SHIP SYNTHESIS MODEL FOR NAVAL SURFACE SHIPS

Michael Robert Reed

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NAVAL SURFACE SHIPS

by

MICHAEL ROBERT REED

Lieutenant, United States Navy

B.S., Iowa State University

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ABSTRACT

Ship Synthesis Model for Naval Surface Ships
by: Michael Robert Reed
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This thesis presents a method for estimating the weight, volume, center of gravity, electric load, and other overall ship characteristics of conceptual as well as existing Naval surface displacement ships. The method is computerized and thus permits rapid calculations of technical characteristics for a much larger number of ship studies than would be permitted by hand calculations. The final program listing is given together with a listing of the empirical relations developed.

The program is applicable to Naval surface displacement ships and has been verified to give accurate results for ships which range in size from 300 to 700 feet in length and 1700 to 17,000 tons in displacement.

The model has been found to have applications in conducting feasibility studies, systems analyses, updating design predictions, and conducting comparative studies. However, due to the aggregation of empirical data, the model should not be used as a substitute for preliminary design studies and should definitely not be used for actual ship design.

The program developed is an attempt to provide a more versatile synthesis model for Naval combatants. The versatility is provided by estimating the characteristics of the ship at a greater level of detail than is generally attempted with a synthesis model and by use of a large input array to override calculated values when desired. The model estimates only technical characteristics and no cost estimations are made.

Thesis Supervisor: Clark Graham
Title: Associate Professor of Ocean Engineering

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CHAPTER 1

INTRODUCTION

1.1 Background

The Conceptual Phase of ship design can be said to be made up of Feasibility Studies and the Concept Design. The Feasibility Study is the first and grossest estimate for a ship. The Concept Design is development and optimization of a single or limited number of selected Feasibility Studies to enhance absolute accuracy. Since a large number of Feasibility Studies are generally required to select a Concept Design, short-cut estimating techniques are often used with emphasis placed on relative accuracy among studies.

Until the early 1960's, Feasibility Studies were performed by the design engineer by completing a time consuming series of standard calculations for each study. Because of the time required to complete the Feasibility Studies, Navy designs of the past relied heavily on designs that had been done previously. These design studies produced what were a set of feasible characteristics. However, because of the limitations on the number of studies which could be conducted, an optimum set of characteristics was probably not obtained.

It was during the 1960's that the U. S. Navy began to look to the digital computer as a means of providing the required calculations to synthesize the ships being studied. By computerizing the calculation process, the designer would be freed from the routine calculations which had taken up most of his time during the earlier stages of design.

With the use of the computerized models, larger numbers of Feasibility Studies could be conducted. Since the optimum solution

is almost always the most desired solution, the designer using a ship synthesis model could conduct many more tradeoffs than in the past and be in a more favorable position when selecting the set of characteristics closest to optimum.

The development of ship synthesis models enabled the engineer to conduct systems level tradeoff studies early in the design on aspects which were seldom considered in detail before. These aspects include hull form, speed, endurance, and payload options, among others.

Another important characteristic of the computer model is that it allows consistency among feasibility studies. The consistency built into the model standard calculations allows the study results to be compared without the possibility of bias favoring certain concepts. With the human element involved in performing the hand calculations, it is difficult to insure that the same assumptions will be made for each study and that no bias is applied.

Several synthesis models for naval ships have been available for a number of years. Two Navy models were referred to extensively in developing the program presented in this thesis. The two models are the U. S. Navy's destroyer model, DD07 (15)*, and Center for Naval Analyses Conceptual Design of Ships Model (CODESHIP) (3).

The destroyer model, DD07, was first developed in the 1960's and has been continually updated since then. This model was developed to model only destroyer type ships. The Coast Guard Cutter Model of Reference (8) was patterned primarily after the

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*Numbers in parenthesis refer to the references at the end of this thesis.

DD07 model. Because of this, Reference (8) was also used extensively in developing the program presented in this thesis.

The general framework of a method of analysis for the CODESHIP model was first conceived at the Center for Naval Analyses in the mid 1960's. CODESHIP was developed to model ships which range in type and size from patrol craft to aircraft carriers. Because of the wide range of ship types and sizes in the data base, the CODESHIP model is probably not as accurate in predicting actual values as a model designed for a specific ship type, e.g., DD07 for surface combatants. The greatest assets of the CODESHIP model are its versatile input and output features.

Existing models appear to be limited in that they do not provide the designer with the capability to change the design standards or practices from those which were built into the program, except for only a few exceptions. These models produce feasible ship results which cannot readily be changed to reflect desired standards or practices. Desired changes can be incorporated by changing estimating relationships or, in some cases, by inputing lump sums of weight or volume which when analyzing the results may be difficult to interpret.

1.2 Statement of Problem

The major problem with the ship synthesis models which currently exist is that they do not have the versatility required to answer many of the more specific questions which arise when considering the ship characteristics produced for any design. The kinds of questions which the models cannot readily answer concern "how the ship might have turned out if certain functional items had been

designed to standards or practices different from those standard calculations built into the model."

In answer to the above problem, this thesis is intended to provide a more versatile Ship Synthesis Model for Naval Surface Combatants. This model should allow the designer to control the design standards and practices to which the ship is designed and to observe the resulting ship characteristics from a more functional level than existing models provide. The model should be based on a set of standard calculations derived from the data base ships, but should offer the designer the flexibility to change the results by inputing values which reflect a different design practice or standard. The resulting model should enable the user to provide a significantly greater number of design options and a correspondingly greater ability to investigate solutions.

1.3 Scope

The program developed in this thesis is an attempt to satisfy the need for a more versatile Ship Synthesis Model for Naval Surface Combatants. With the growth of systems engineering in ship design, a more versatile model would allow the designer to place additional emphasis on tradeoffs at all phases of the design.

The model developed in this thesis is intended to have applications not only during the conceptual phase of design, which has been the traditional use for synthesis models, but during later phases of the design as well. The program is intended to have a variety of applications to ship design, but primarily as a model for conducting feasibility studies, a design aid for updating predictions in later stages of design, and as a tool

for conducting Comparative Naval Architecture Studies.

With the model developed and ready for use, the next step was to run several ship designs to allow for analyzing the results and determining if the desired versatility could be achieved. The results are discussed in Chapter 4.

The model is limited to surface displacement ships configured as naval combatants. Therefore, the model should not be used for synthesizing merchant types which are constructed to commercial standards. The weight data for the sample ships used in the development of the model ranges from full load displacements of 1770 to 16,294 tons. The length between perpendiculars for ships in the data base ranges from 301 feet to 700 feet. Therefore, designs that required extrapolations to very low or high values within individual component categories should not be made without additional investigations as to the reasonableness of the particular extrapolation.

The ship synthesis method developed is designed to provide detailed technical characteristics of the ships modeled. However, no cost characteristics are calculated by the model and are considered beyond the scope of this thesis.

1.4 Presentation of Thesis

Chapter 2 gives a general program description for development of the model. Sections are provided to discuss the methodology for program development and to explain the top level program flow.

Chapter 3 gives a detailed description of each of the subroutines used in the model.

Chapter 4 gives an evaluation of the model including results

of test runs made.

Chapter 5 contains conclusions and recommendations.

Appendix A services as a users guide to the program by providing a description of the input and a shopping list for payload items.

Appendix B gives a sample output listing.

Appendix C gives the classification systems used for volume and weight assignment.

Appendix D is a listing of all the equations derived from sample ship data to provide the calculations required in the model.

Appendix E is a listing of the program.

Appendix F is the nomenclature list for the entire thesis.

It is recommended that at least Chapters 1, 2, 4, 5 and Appendix A be read before attempting to use the program. The important aspects of each subroutine are covered in Chapter 3 which may be omitted without loss of continuity by anyone not interested in the details of the program.

CHAPTER 2

GENERAL SYNTHESIS MODEL DESCRIPTION

2.1 Introduction

This chapter gives the overall description of the solution method used to develop the synthesis model, as well as, the method used within the computer program to complete the ship calculations. The detailed description of the program is contained in Chapter 3.

Section 2.2 gives the methodology which was employed to arrive at the final model. Included in this section is a discussion of how the principal features of the program were selected and how they were incorporated in the model.

Section 2.3 discusses the overall program flow. This section explains the program execution required to complete a feasible ship design and indicates the iteration cycles required to obtain the degree of accuracy desired.

2.2 Methodology for Program Development

The design estimates produced by a synthesis model should be tailored to meet the conditions required of a feasible solution. First, there must be a balance between weight and displacement (Archimedes Principle). Second, internal space available must be equal to or greater than internal space required. In recent years this area/volume requirement has become the dominant factor in setting the size of U. S. Naval ships. The area/volume requirement complicates the synthesis model significantly, since detailed geometry calculations are required to provide the checks required. Third, the energy available must at least meet the energy required,

i.e., propulsion, auxiliary, and electrical power requirements must be met. Finally, the distribution of weight and volume must be such as to satisfy design criteria for transverse stability, girder strength, and seakeeping. These conditions for a feasible solution require iterative processes within the model to obtain a satisfactory solution.

The first step in developing a more versatile synthesis model was to develop a list of items or features for which input flexibility would be desirable. Table 1 lists several functional areas of the ship system where flexibility in model input would be desirable. This list of functional groups closely follows that of the U. S. Navy Space Classification System of Reference (17). By covering all of the functional groups, the list suggests that it would be desirable to be able to input or at least influence the design emphasis and establish design standards for a specific functional area when synthesizing a ship to a set of requirements.

Model flexibility for several ship models is indicated in Table 2. In this table the areas of desired flexibility have been more specifically defined. Model flexibility has been indicated by an "X" for the U. S. Navy DD07 Destroyer Model (15), the Coast Guard Cutter Model (8), the CODESHIP Model (3), and the author's model. An "X" marked for an area of flexibility does not imply that the model has complete flexibility in that area or can handle all situations desired. It does mean that the model has some flexibility to control how the feature is considered.

The selection of features to be included in the model was based on availability of data and the capability to incorporate

TABLE 1

AREAS OF DESIRED FLEXIBILITY

*MILITARY MISSION	
Communication & Detection	
Weapons	
Aviation	PAYLOAD ITEMS
Special Missions	
Cargo	
*PERSONNEL	
Living	
Support	HABITABILITY
Stowage	
*SHIP OPS	
Control	
Main Propulsion Machinery	
Auxiliary Systems	
Maintenance	MOBILITY AND SHIP SUPPORT ITEMS
Stowage	
Tankage	
Passageways and Access	
*HULL	STABILITY, STRUCTURES, ARRANGEMENTS, AND FORM
*SYSTEMS ENGINEERING	GENERAL ITEMS

TABLE 2

MODEL FLEXIBILITY

FLEXIBILITY INCORPORATED				AREAS OF DESIRED FLEXIBILITY
DDO7*	CUTTER*	CODESHIP*	MODEL	MILITARY MISSION
X	X	X	X	Electronics
X	X	X	X	Armament
X	X	X	X	Ammunition
X	X	X	X	Aircraft
X	X	X	X	Other Selected Items
				PERSONNEL
X	X	X	X	Accommodations
X	X	X	X	Separate OFF, CPO, ENL
X	X	X	X	Endurance Days Provision
			X	Messing, Rec., & other Support Services
			X	Potable Water & Personnel Stowage
				SHIP OPS
X	X	X	X	Power Plant Type
X			X	Electrical Plant Type
		X		Engine Location
		X	X	Shaft Type
X	X	X	X	Number Shafts
X	X	X	X	Sus. & End. Speed, Range --- H.P.

*DDO7 is the U.S. Navy Destroyer Model described in Reference (15). CUTTER is the Coast Guard Cutter Model in Reference (8). CODESHIP is the Center for Naval Analyses Model in Reference (3).

TABLE 2 (continued)

FLEXIBILITY INCORPORATED				AREAS OF DESIRED FLEXIBILITY
DD07	CUTTER	CODESHIP	MODEL	SHIP OPS
X	X	X	X	Max. H.P. & Mach. Box Size --- Speed
			X	Maintenance & Stowage
			X	Passageway & Access Space Provided
X			X	Auxiliary Systems
			X	Office Space
X		X	X	Other Selected Items
				HULL
X	X	X	X	Hull Shape (Coef. & Dim.)
X	X	X	X	Hull Coating
		X		Hull Subdivision Std.
X	X	X	X	Hull & Superstructure Material
		X		Superstructure/Hull Ratio
			X	Structures
X	X	X	X	Stability(GM/B, F.S.)
X	X		X	Space Available
				SYSTEMS ENGINEERING
X	X		X	Ship Protection Level
X		X	X	Tolerance for Iterations
X	X	X	X	Design Margins
			X	Ship Silencing

the feature into the program within the required time frame. The ships used as the data base for developing model relationships were:

FF 1006	DL 1
FF 1033	DL 2
FF 1037	CG 9
FF 1040	CG 16
FF 1052	CG 26
FFG 7	CGN 25
DD 445	CGN 35
DD 692	CGN 36
DD 931	CGN 38
DD 963	CGN 9
DDG 2	

The versatility of the model is best understood by referring to the Users Guide of Appendix A. The versatility is generally accomplished by use of the following techniques:

a. input elements for problem specifications;

b. options on selecting several ship features;

c. payload shopping list for selection of payload items;

d. calculations of BSCI* weight groups, vertical centers of gravity for all weight groups, volume groups, and electric load groups which are not defined as input items (groups defined in Appendix C);

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*BSCI--"Bureau of Ships Consolidated Index of Drawings, Materials, and Services Related to Construction and Conversion" of February 1965 as given in an appendix to Reference (20).

e. option to override the calculation of any weight group, vcg, volume group, or electric load group by direct input;

f. elements for inputing miscellaneous specifications (mainly habitability coefficients);

g. elements for inputing miscellaneous payload not on the shopping list; and,

h. results displayed in a detailed output listing.

A new functional classification system was developed to aid in the analysis of results and to assist as a comparative tool when assessing the impact of a function on ship design. The functional classification system is listed in Appendix C, and is derived from selecting the appropriate volume and weight groups for each function. This classification system enables a density to be calculated for each function.

After deciding what features to use, how to incorporate the versatility, and developing a classification system, the required relationships to complete the model were derived using data gathered from the ships previously mentioned. The relationships derived are given in Appendix D and include the following:

a. starting estimates for full load displacement and center of gravity;

b. some geometry relationships;

c. linear fit to powering curves;

d. weight equations;

e. vertical center of gravity equations;

f. volume equations;

g. electric load equations; and,

h. equipment sizing relationships.

With the above completed, the computer model was ready to be constructed. The model was formed by taking what were judged to be the best features of the existing models and incorporating the flexibility desired into the program. The general features of the model formulation can be summarized as below:

a. input and output are patterned after the CODESHIP Model (3);

b. geometry, horsepower, electric plant, machinery liquids, volume, weight, vcg, sheer, sea speed routines and internal flow of program are much like DD07 and the Coast Guard Model;

c. model uses all of the derived relationships found in Appendix D and incorporates the logic for the versatility items;

d. results are converted to the new functional classification system and BSCI groups for output; and,

e. a summary of results is selected to include the overall ship characteristics.

The model developed does not attempt to define or check the arrangements required for the ship. Because of this, highly arrangement dependent calculations cannot be performed. These would include damaged stability, topside arrangement, longitudinal balance, and strength calculations. However, for many ship types there is sufficient flexibility in the arrangement of the design to allow a satisfactory solution in these areas to be attained.

2.3 Program Flow

The program is controlled by the main program. The main

program calls the subroutines as required to calculate information for output and to let program execution proceed. Program control organization is shown in Figure 1.

The logical program organization or top level schematic of program flow is shown in Figure 2. This figure indicates how the program solves each problem.

The program begins by reading in the following data:

a. names of items to be printed in the output;

b. residual resistance coefficient values taken from the Taylor Standard Series (7); and,

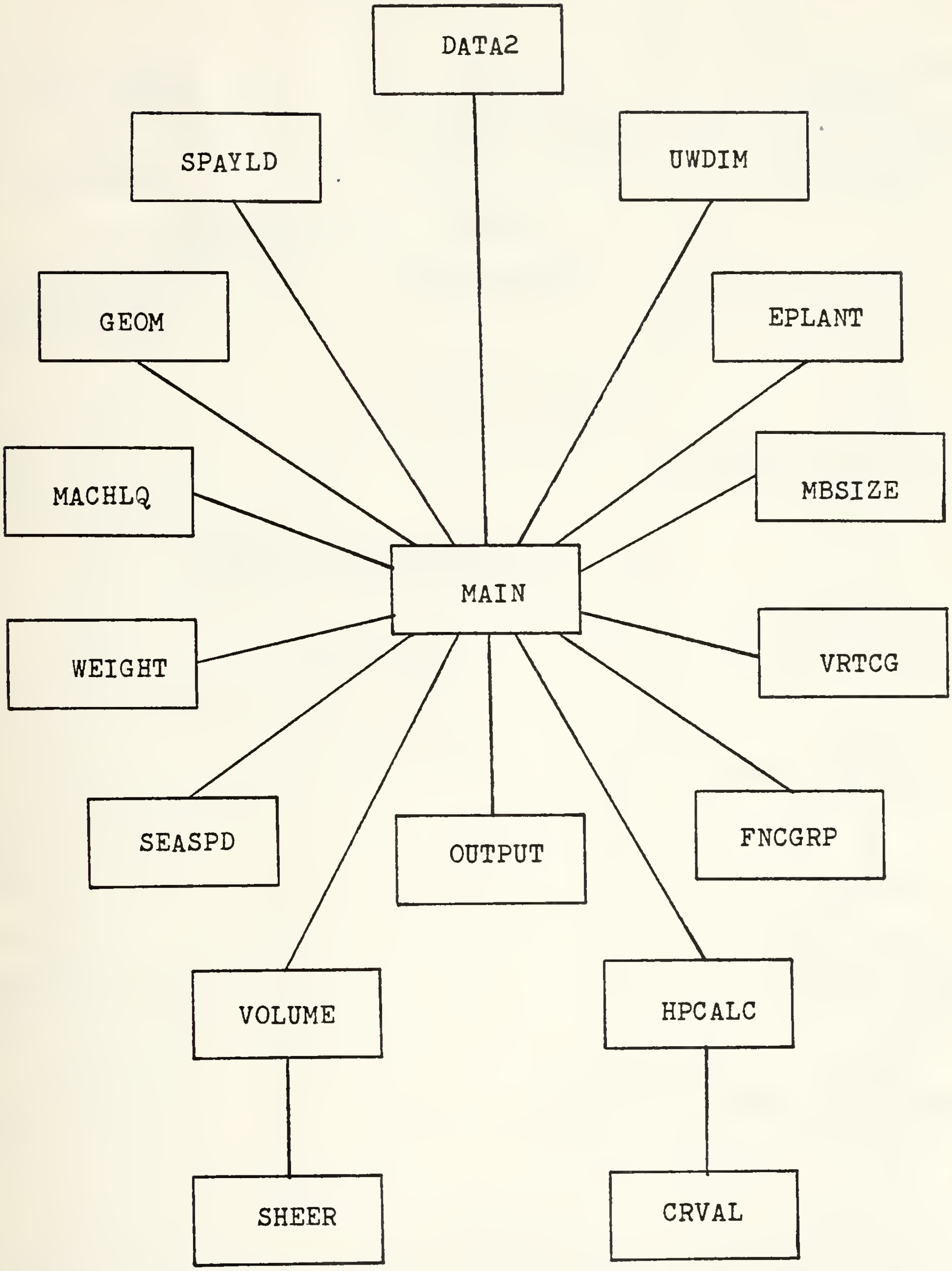
c. data for all the items in the payload shopping list.

This data is read in only once and is used for calculations on all of the ships being run.

The next step is to read in the specifications for the next ship to be run. It is this point in the program where control returns upon completing the output of a ship. The ship data is read in using subroutine DATA2 which allows unformated data to be read into arrays for storage.

The program next calls subroutine SPAYLD which is used to sort the weights of the payload items input and place them in the proper BSCI weight group. The value of WPAYIN, the total weight of payload input, is calculated to be used for the initial estimating of full load displacement should the value of LBP not be specified.

At this point the underwater shape of the hull is calculated. If the LBP is given as input, control passes to subroutine UWDIM. Values input to this subroutine are LBP, free surface correction, C_p, C_x, GM/B, as well as estimated KG and full load displacement.



PROGRAM CONTROL ORGANIZATION

Figure 1

LOGICAL PROGRAM FLOW

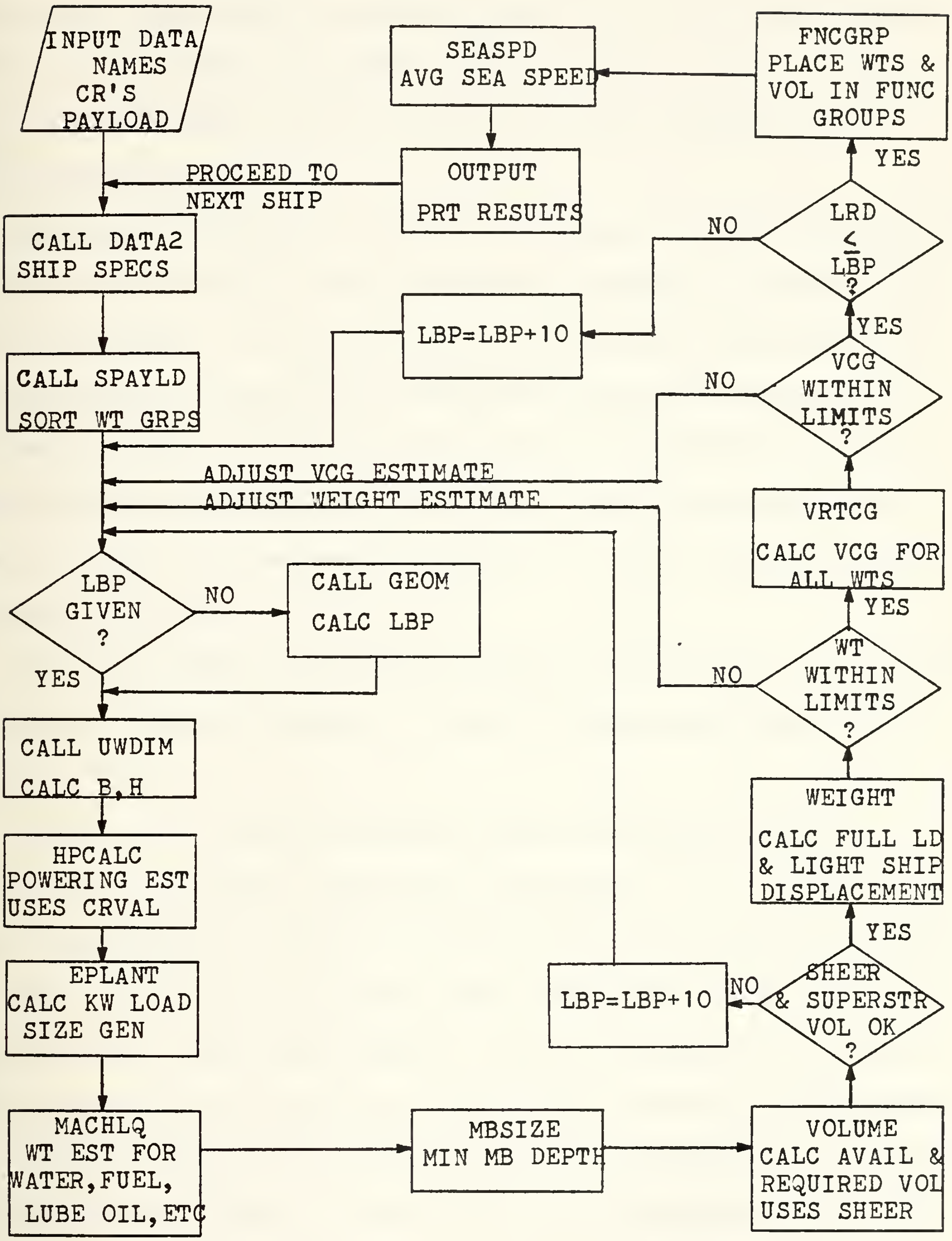


Figure 2

Output values from this subroutine are B, H, and C_{wp}.

If LBP is not an input, but values for L/B and B/H are input, the control first goes to subroutine GEOM where LBP is calculated. UWDIM is then called to complete the calculations for B, H, and C_{wp}. Inputs to GEOM are L/B, B/H, C_p, C_x, and estimated full load displacement.

Subroutine HPCALC is now called to determine either the maximum sustained speed, VSUS, or the horsepower required at maximum sustained speed, SHP. If VSUS is input, then HPCALC along with subroutine CRVAL, estimates the horsepower required to maintain the maximum sustained speed. If SHP is input, then HPCALC is used to compute VSUS. HPCALC is written to take speed as an input and return a value of horsepower; therefore, to find VSUS an iterative procedure is used.

Subroutine HPCALC is called on again to determine the horsepower required at endurance speed. A value for endurance speed must be input.

HPCALC uses a Taylor Standard Series horsepower estimate. Values for the residual resistance coefficient, C_r, are stored in arrays and subroutine CRVAL is used to choose the correct C_r value.

The program is now ready to make the electric plant related calculations. Subroutine EPLANT is used to determine the cruise, battle, and 24 hour average electric loads, and also, to determine the number and size of generators required, if they are not specified.

Subroutine MACHLQ is called next in the program to calculate the weight of potable water, reserve feed water, ship lube oil, fuel oil and diesel oil. These weights are calculated at this

point since they are used to determine the associated tankage volume which is calculated before the rest of the ship weights are found.

The minimum depth for the machinery box must be determined since this is also the minimum depth which the ship can have. Subroutine MBSIZE is called next to make this calculation.

The program is now ready to calculate both the required and available volumes for the ship and to make adjustments to the ship geometry to balance these requirements. Since most U. S. Navy surface ships are considered to be volume limited, this volume balance is perhaps the most important iteration in the design. Subroutine VOLUME supplies all of the volume calculations and adjustments which include the following:

a. calculation of the volume required for all of the functional groups of Appendix C;

b. use of subroutine SHEER to determine an acceptable sheer line and resulting depth at stations 0, 10, and 20;

c. adjustment of superstructure size to achieve volume balance, if possible;

d. addition of a raised deck if additional volume is required;

e. consideration of tankage space available and flare of ship in determining usable arrangement volume; and,

f. increment to length if the maximum superstructure volume available is insufficient or if an acceptable sheer line cannot be found.

The weights of all light ship and load items which are not payload input are next determined in subroutine WEIGHT. At the

completion of WEIGHT, the new full load displacement is compared to the previous estimate. If the two values are within the displacement tolerance required, a balance has been reached and the program proceeds to estimate the vertical center of gravity. If the two values are not close enough, a new estimate is made and control is returned to either GEOM or UWDIM to reestimate the dimensions.

Subroutine VRTCG is now called to estimate the vertical center of gravity of all weight groups including the payload associated groups. The estimated VCG for the ship is compared to the previous estimate. If the difference is less than the allowed difference, control proceeds on, but if they are not close enough control goes back to GEOM or UWDIM.

A check is made at this point to see if a long raised deck (LRD) was added which is longer than the LBP. If the value of LRD is greater than LBP, a message is printed and the length of the ship is increased by 10 feet and control returned to UWDIM. If LRD is less than or equal to LBP, a balanced and feasible ship has been calculated.

Subroutine FNCGRP is called next to place the weights and volumes calculated into the proper functional groups as described in Appendix C.

An estimate of the speed the vessel will be able to sustain in the North Atlantic Ocean is made in subroutine SEASPD. The output of SEASPD offers a means of making a relative comparison of seakeeping characteristics between ships.

Finally, subroutine OUTPUT is called to print the results. The input specifications are printed first, followed by the payload

input, summary of results, functional group results, BSCI weight listing, and functional electric loads.

Details of each subroutine and the main program are contained in Chapter 3.

CHAPTER 3

DETAILED PROGRAM DESCRIPTION

3.1 Introduction

This chapter provides a discussion of the detailed flow of the program. The main program and each of the program subroutines are discussed to the level of detail necessary to explain how the required calculations are made. The step-by-step analysis of the model program is left to the reader. A program listing is provided in Appendix E.

Section 3.2 provides the discussion of the main program. All subroutines are discussed in sections 3.3 through 3.18 in the order in which they are called by the main program.

3.2 MAIN Program

The MAIN program controls the execution of each trial case. All but two of the remaining subroutines are called from the MAIN program. A flow chart from this routine is given in Figure 3.

The real, integer, data, dimension, and labeled common statements used are first defined. Labeled common statements are used throughout the program to transfer data and save computer storage area.

The program next reads in values from data for the following:

a. specification names;

b. type names;

c. summary of result names;

d. functional component names;

e. BSCI weight group names;

MAIN PROGRAM FLOW CHART

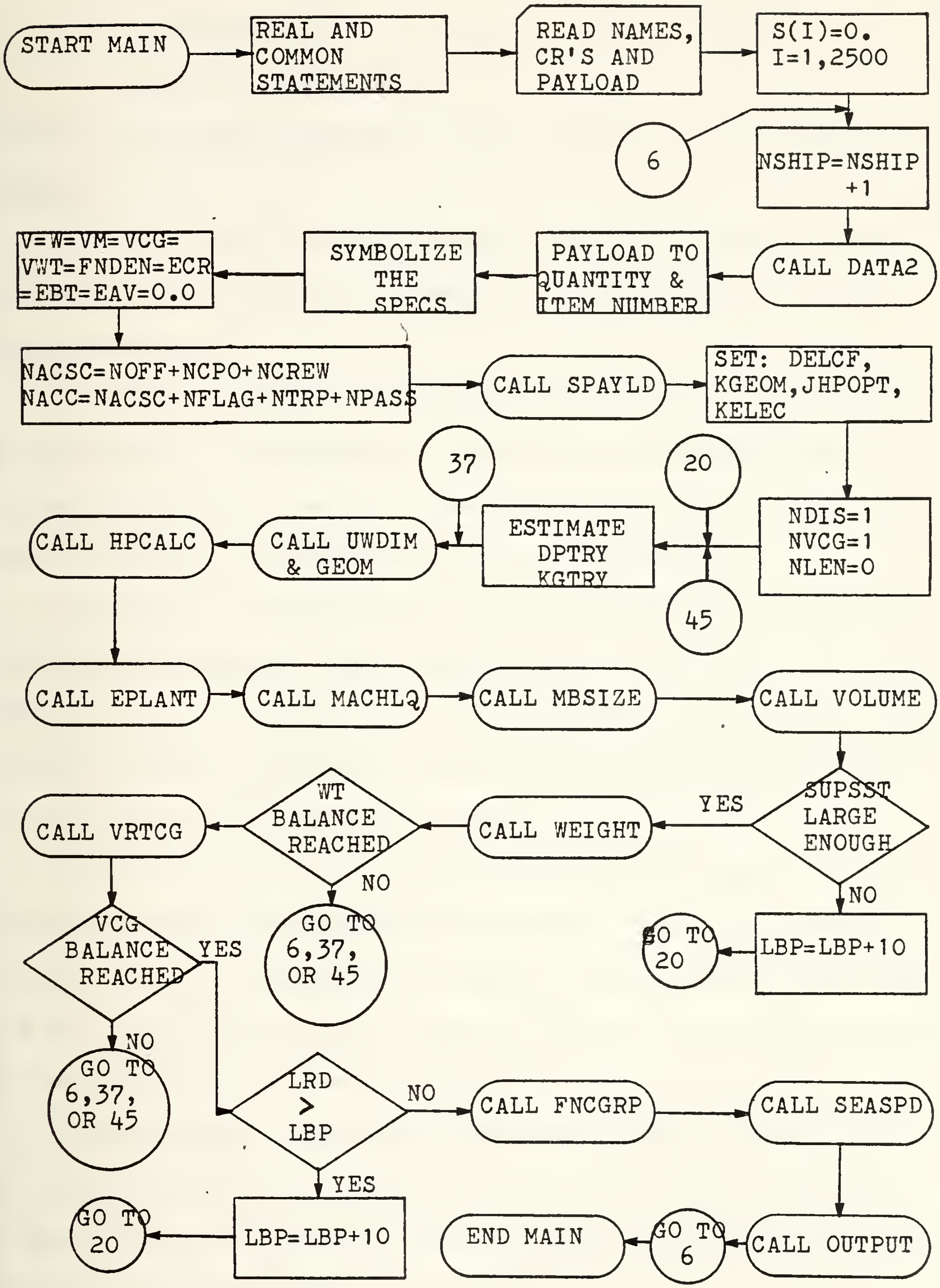


Figure 3

f. electric functional group names;

g. C_r array; and,

h. payload shopping list.

The data for items a through g above is given in the listing of Appendix E.

The input specification array is now initialized to zero. The ship number index is incremented to show the current ship being calculated.

The specification items for the next ship are read in next. The program now transforms the payload specifications input to a quantity of each item and an associated item number which is used to refer to the payload for later calculations.

The input specifications are now symbolized to allow for easier identification within the program, e.g., VSUS = S(1) and VEND = S(2). The arrays used to store results for volumes, weights, vertical centers, densities, and electric loads are initialized to zero before the calculations begin.

The calculation is now made to compute the number of ships company and total accommodations required. Subroutine SPAYLD is now called to calculate the weights of the payload items input and the total weight of the payload, WPAYIN, which may be required for an initial displacement estimate.

The frictional resistance correction factor, DELCF, is now set equal to .0004 if no value is specified in the input array. Program pointers for calculating ship geometry, horsepower, and electric plant are next set as follows:

a. KGEOM = 0 if LBP = 0, KGEOM = 1 if LBP > 0;

b. JHPOPT = 1 if SHP = 0, JHP = 2 if SHP > 0; and,

c. KELEC = 0 if electric plant size is not given, KELEC = 1 if electric plant size is given.

The program next initializes the counters used for iteration of weight, vcg, and length. An initial estimate of full load displacement is made at this point. These equations as well as all others used in the program are found in Appendix D. If LBP is given the program goes to subroutine UWDIM to calculate the dimensions. If however, L/B and B/H are given instead of LBP, subroutine GEOM is used to obtain LBP, and then UWDIM is called. Values received from UWDIM are B, H, and C_{wp}. An initial value for KG is also estimated in the MAIN program at this point.

The propulsive coefficients at endurance and maximum speeds are now set, if not specified. Subroutine HPCALC is used to obtain values for VSUS, SHP, and horsepower at endurance speed. If SHP is given, then VSUS is calculated or the reverse if VSUS is provided. When the maximum sustained horsepower is specified, a modified Newton-Raphson technique is used as in Reference (8), with the slope approximated by a secant to the speed-power curve, to calculate VSUS.

Subroutine EPLANT is called next to calculate the electric loads and size generators, if not given. MACHLQ is called to obtain the weight of liquid load items. The next subroutine used is MBSIZE to estimate the minimum machinery box depth.

Subroutine VOLUME is used to calculate the volumes required for all functional groups and to size the superstructure and ship depth to meet the requirements. If the largest superstructure

size acceptable is not big enough, the LBP is increased by 10 feet and calculation of the ship starts over.

The BSCI weight groups are now estimated in subroutine WEIGHT. A modified Newton-Raphson technique is used to iterate full load displacement until convergence between estimated and calculated values is obtained. The method used is described in detail in Volume II of Reference (3). If a weight balance cannot be reached within the specified number of iterations, a "no balance" message will be printed and the next ship will be called.

The vertical center of gravity for all weight groups is calculated in subroutine VRTCG. A check is made for convergence of the vertical center of gravity estimate for the ship. The average of the estimated and calculated values is used to iterate the KG try. If the vcg counter exceeds the allowed number of iterations, a "no balance" message is printed and the next ship tried.

A check is next made to see if a long raised deck was added and if that length was longer than LBP. If LRD is greater than LBP, then LBP is increased by 10 feet and the ship is recalculated.

Once the ship size is set, the next step is to calculate the functional weights and volumes according to Appendix C. This is done by subroutine FNCGRP. The density of each function is also calculated in pounds per cubic foot.

Subroutine SEASPD is now called to estimate an average sustained speed in the North Atlantic Ocean. Subroutine OUTPUT is called last to print the ship results. Control now returns to the beginning to input the next ship.

The listing of the MAIN program concludes with a listing of

print and format statements which are used if any default option is encountered. The default is printed and control returns for the next ship input.

3.3 Subroutine DATA2

Subroutine DATA2 was adapted from Reference (13) for use in reading the data for each ship. The detailed description of the subroutine as well as the detailed flow charts may be found in the reference and are not reproduced here. The subroutine was found to be very useful for a program like the ship synthesis model, since it allows format free data to be input into arrays or matrices for easy storage and manipulation.

Each card to be read using DATA2 must begin with an address field followed by one or more value fields. A field is defined as a group of characters terminated by a blank. A field having the last non-blank character in column 72 of the data card is acceptable. The address refers to the location in a given array in which a data item is to be stored.

The value fields are the data items being input and are of the form

$\pm$ A ...AA.aa...a $\pm$ B...BB.bb...

which is interpreted as

$\pm$ A...AA.aa...a x $10^{\pm B...BB.bb}$

The portion represented by the A's is called the coefficient; the portion represented by B's is called the exponent. An unsigned coefficient is assumed to be positive. For example the card:

14 1+1 21.2 -7-3

would yield 10 as the 14th element in a given array, 21.2 as the

15th element and -.007 as the 16th element.

The address may be multi-dimensional, e.g., the card:

1,1,4 17.2

would place 17.2 in element (1,1,4) of the given array. There is no limit to the number of dimensions used.

No alphabetic characters will be accepted by the routine. Also care must be taken when several value fields are given on a card with a multi-dimensional address. For example, when reading in the payload, element (1,4) is followed by element (2,4) since there are 7 rows in the payload matrix, P(7,300).

If data items were to be entered into a singly dimensioned array, e.g., S, the calling sequence to DATA2 would be

CALL DATA2 (S, IND, 2500)

where 2500 is the size of the array and IND is a fixed point indicator having the following possible values upon returning to the MAIN program.

(1) IND = 0 - Routine encountered a blank card read. No following cards were read. By using a blank card as the last card of a data set, this becomes the normal return value.

(2) IND = 1 - Routine found the first card read was a blank card. No following cards were read. By using a blank card as the last card of an input deck, this return indicates the end of the input deck has been reached.

(3) IND = 2 - An unacceptable data card was read. No following cards were read and an error

message was written of the form, "BAD DATA CARD . . . (card image)".

For a multiple dimension array, such as P(7,300), the subroutine DATA2 would be entered by

CALL DATA2(P, INDP, 2100)

where INDP is a 3-item array. The array in this case happens to be INDP(1) = 2 (the number of dimensions of P), INDP(2) = 7 (size of the first dimension), and INDP (3) = 300(size of the second dimension). Upon returning from DATA2, INDP(1) serves as the indicator and would have the above-mentioned possible values of IND.

3.4 Subroutine SPAYLD

Subroutine SPAYLD is used to sort the weights of the payload items into the proper BSCI weight groups. The subroutine checks each item of payload to see which weight group it should be placed in. SPAYLD then multiplies the quantity of the item times the weight per item and places the result in the weight array element corresponding to the weight group. The flow chart for this subroutine is given in Figure 4.

The final result provided in the subroutine is the total weight of all payload items input. This total payload weight, WPAYIN, may be required by the MAIN program to estimate full load displacement.

3.5 Subroutine GEOM

Subroutine GEOM is used to provide a value for the length of the ship if LBP is not input. If LBP is input to the program, GEOM is not used. The flow chart for GEOM is given in Figure 5.

SPAYLD SUBROUTINE FLOW CHART

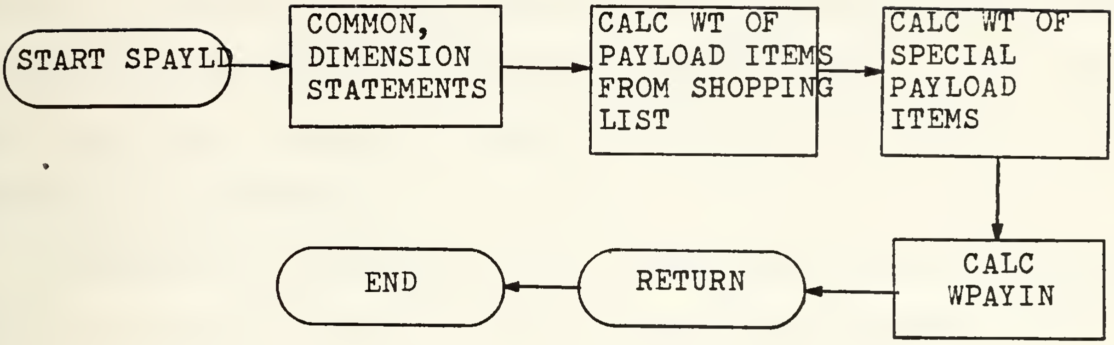


Figure 4

GEOM SUBROUTINE FLOW CHART

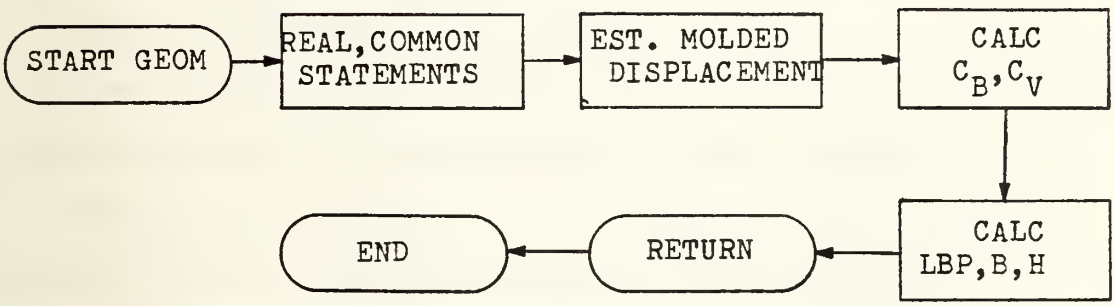


Figure 5

When it is required to use GEOM, values for the estimated full load displacement, C_p, C_x, L/B and B/H are used with the standard geometry equations of naval architecture to provide the unconstrained dimensions of the ship. Besides a value for LBP, B and H are also calculated, but may be changed later in the program to satisfy stability requirements.

Throughout the program, it is assumed that the total displacement is 1.4 percent greater than the molded displacement. The molded displacement is used for the calculations of GEOM.

3.6 Subroutine UWDIM

The values for beam and draft are calculated in subroutine UWDIM. Inputs to this subroutine are length, C_p, C_x, displacement try, KG try, and GM/B. The waterplane coefficient, C_{wp}, is also calculated, but only as a linear function of C_B. A flow chart for this subroutine is shown in Figure 6.

Since displacement is an input to this routine, the value of beam times draft is fixed as:

$$B \times T = \text{Displacement} \times 35./(\text{LBP} \times C_p \times C_x)$$

Reference (2) may be referred to for a detailed definition of naval architecture variables used in this routine.

The beam to draft ratio, B/H, is determined by the GM/B criterion where GM available is given by the formula:

$$GM = KB + BM - KG - \text{Free surface correction}$$

A value for KB is estimated using Morrish's approximate formula:

$$KB = H - 1/3 \times (H/2 + \nabla/A)$$

where: H is the draft in feet

UWDIM SUBROUTINE FLOW CHART

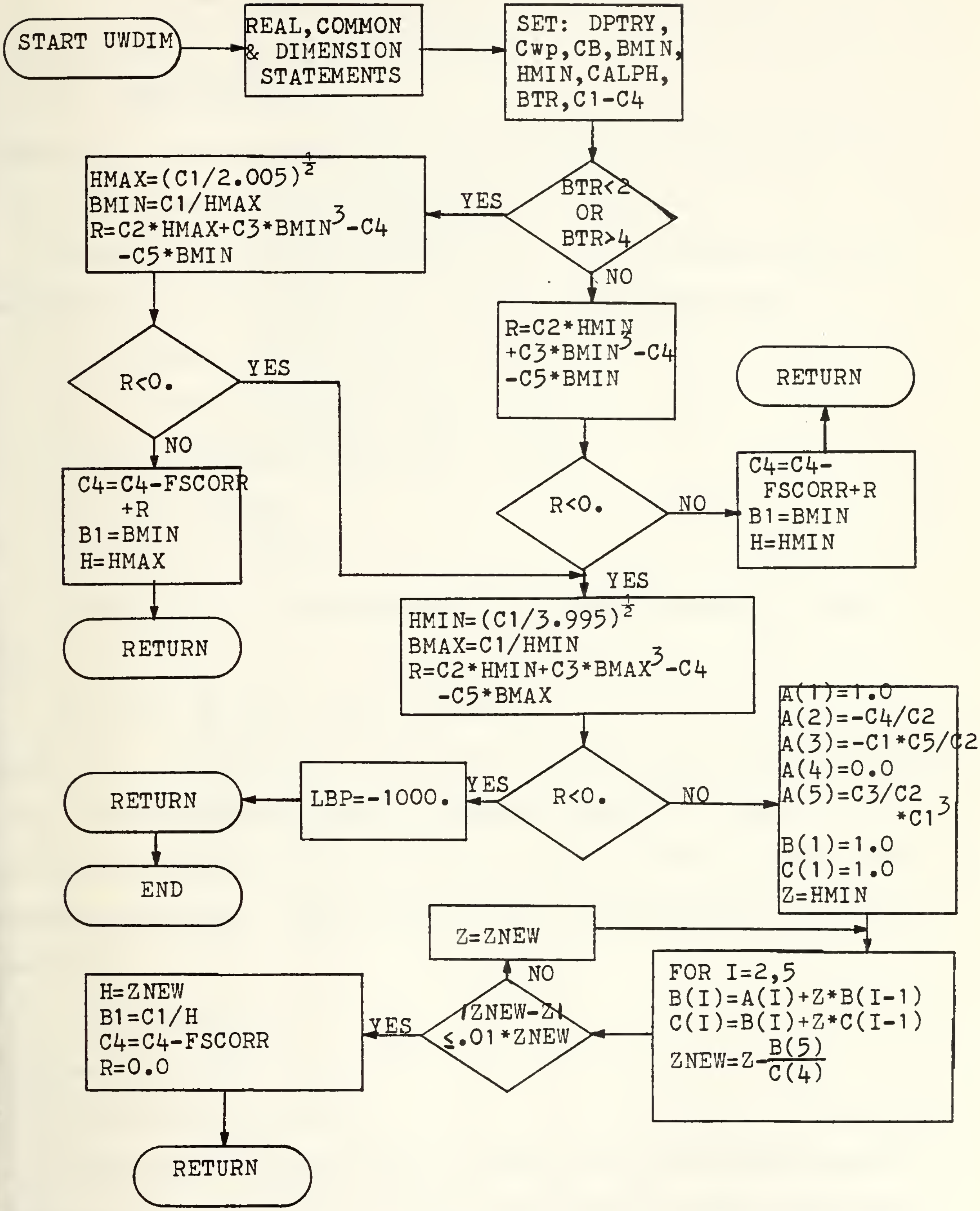


Figure 6

∇ is the volume of displacement = B x H x LBP x C_p x C_x, ft^3.

A is the waterplane area = B x LBP x C_{wp}, sq. ft.

A value for BM is estimated using:

$$BM = \frac{LBP \times B^3 \times C_\alpha}{\nabla}$$

where C_α is a transverse moment of inertia coefficient which is assumed to be a linear function of C_p.

A number of coefficients are used in this routine which are defined by the above equations. These coefficients are:

$C1 = DPTRY * 35./(LBP*C_p*C_x) = B \times H$

$C2 = .833 - C_p * C_x/(3.*C_{wp}) = KB/H$

$C3 = LBP * CALPH/(DPTRY*35.) = BM/B^3$

C4 = KG + FSCORR

C5 = GM/B = GMBMIN

A variable R is introduced in the subroutine with a value of:

R = KB + BM - GM - KG - FSCORR

When R = 0, the stability criterion that GM = C5 x B is just satisfied. This condition gives the desired solution. However, the solution is only valid provided the value for beam to draft ratio remains within the limits specified by the speed-power estimation which are:

$2.0 \leq B/H \leq 4.0$

or since B = C1/H

$(C1/4)^{\frac{1}{2}} \leq H \leq (C1/2)^{\frac{1}{2}}$

The solution method used to obtain the final dimensions of the ship is an iterative one and is described in full detail in Reference (8).

3.7 Subroutine HPCALC

Subroutine HPCALC performs the speed-power estimates required by the program. The subroutine uses the Taylor Standard Series power estimation of Reference (7). The procedure used is very nearly that of the hand calculating procedure. The flow chart for the subroutine is given in Figure 7.

Two problems of interest arise with regard to doing the calculations on a computer. The first problem is choosing the correct value for the residual resistance coefficient, C_r, from the curves of Reference (7). The method for obtaining C_r in the program was taken from Reference (8) where the C_r curves are converted to array form and stored in the program. Subroutine CRVAL, described in the next section, chooses the correct value of C_r from this stored array.

The second problem is that of computing the surface area of the hull. This is accomplished by using the equation developed in Reference (8) which is:

$$S = (1.7 \cdot L \cdot T + \nabla/T)(.0053(B/T)^2 - .02(B/T) + 3 \cdot C_v + .08 \cdot C_p + .926)$$

Although this formula may not be the most accurate method, it is considered to give values within 5 percent of the values calculated from the curves of Reference (7) over the entire range. The results are considered to be very satisfactory for the program and further refinement in this area was not considered necessary.

Also, linear approximations to the curves of Reference (9), used for calculating effective horsepower with appendages and effective horsepower total, once effective horsepower bare hull is

HPCALC SUBROUTINE FLOW CHART

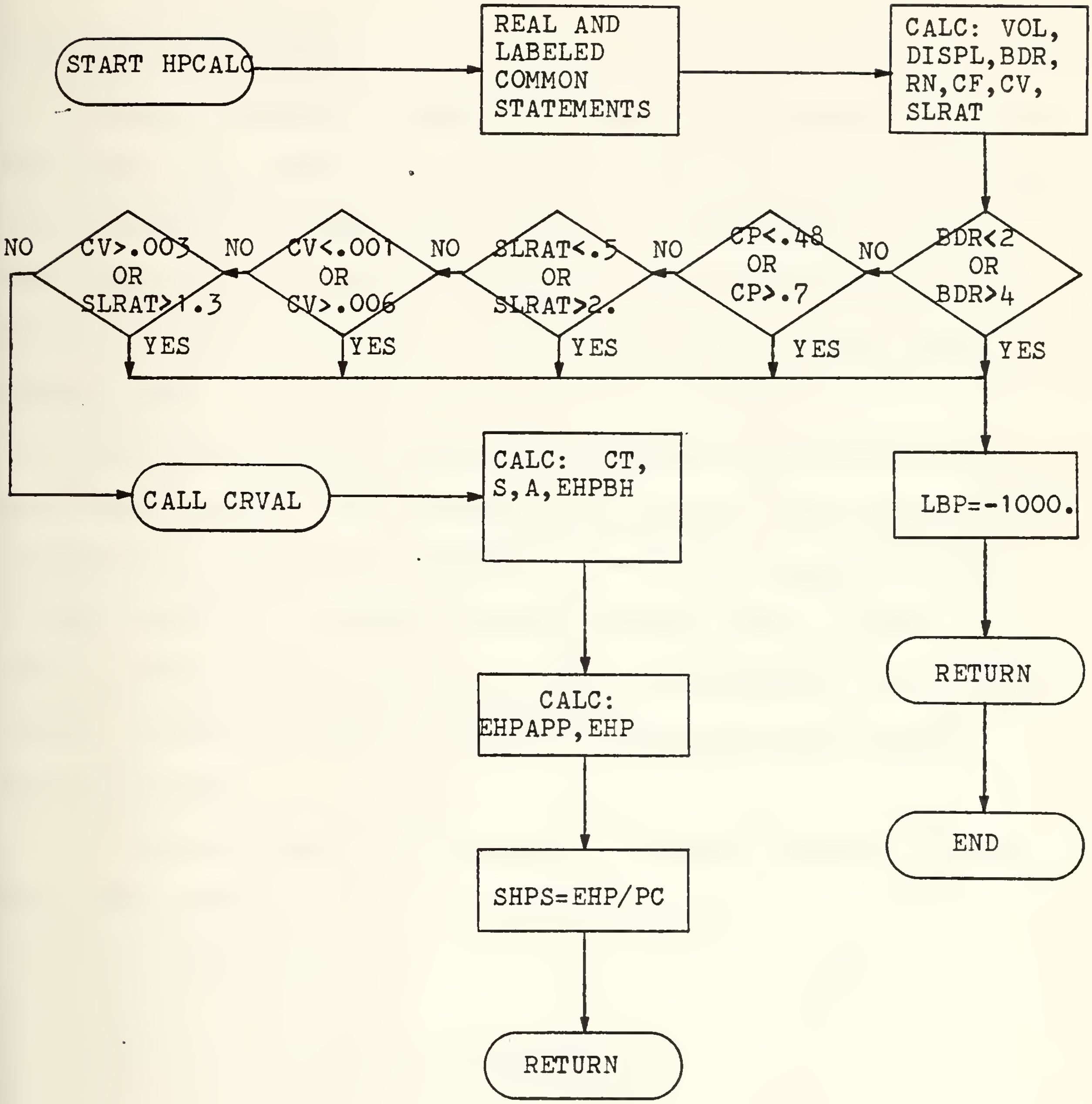


Figure 7

known, are included in the subroutine. These equations are listed in Appendix D.

3.8 Subroutine CRVAL

The only function of subroutine CRVAL is to choose from stored data arrays the values of the residuary resistance coefficient, C_r, which straddle the input point and then to interpolate to find the value of C_r at the input point. The input point is specified by the four variables: beam to draft ratio, C_p, C_v, and speed length ratio.

The CRVAL subroutine used in the program was taken directly from Reference (8). The constants stored in the three arrays which contain the C_r data were originally determined using the curves of Reference (7). Although the three arrays (CR1, CR2, and CR3) are each one dimensional, the data they contain is four dimensional, varying with each of the four variables which specify the input point.

The maximum ranges for the input variables that are accepted are listed below:

$2.0 \leq B/H \leq 4.0$

$.48 \leq C_p \leq .70$

$.001 \leq C_v \leq .006$ for $0.5 \leq V/\sqrt{L} \leq 1.3$

$.001 \leq C_v \leq .003$ for $0.5 \leq V/\sqrt{L} \leq 2.0$

Sixteen values of C_r are required to straddle the input values of B/H, C_p, C_v, and V/ L. After these sixteen numbers have been chosen, the value of C_r at the input point is found by interpolation. A total of fifteen interpolations are required, eight to select the correct speed length ratio, four to select the

correct C_p, two to select the correct beam to draft ratio, and a final one to select the correct C_v.

A more detailed description of the subroutine and the subroutine flow chart are found in Reference (8).

3.9 Subroutine EPLANT

Subroutine EPLANT performs two basic functions. The first is to estimate the functional electric loads for cruise, battle, and 24 hour average conditions for use in sizing the electric plant, if required, and in calculating fuel requirements. The second function is to size the generators, if the size is not input. The flow chart for the subroutine is given in Figure 8.

The ships used in developing the electrical load relations were:

FFG-7	FF-1052
DD-963	CG-9
DDG-2	DDG-FY 67
FFG-1	

The equations which were derived for estimating the electrical loads and sizing the electric plant are given in Appendix D. Electric loads for cruise, battle, and 24 hour average are calculated for the following groups:

Group	Function
100	Propulsion Auxiliaries and Steering
200	Auxiliary Machinery
300	Deck Machinery
400	Shops
500	Interior Communications and Electronics

Group	Function
600	Ordnance System
700	Hotel
800	Air Conditioning and Ventilation
900	Power Conversion Equipment

An electric load growth margin is also applied to each group and a group total is calculated to include the margin. The growth margin is generally added to new designs and major conversions to provide sufficient generating capacity for the entire life of a ship. For combatant ships the margin is usually taken to be 30 percent.

The subroutine first calculates the cruise loads, followed by the battle loads, and then the 24 hour average loads. At this point a test is made to determine if the electric plant size has been specified. If the electric plant is input, the subroutine has only to total the number of generators input for ship service and emergency use and determine the ship service, emergency and total installed generating capacities.

If the electric plant size is not input, the subroutine then performs the calculations and checks required to size the plant. Once the size is determined, the type of ship service and emergency generators is checked and the final number of each type generator is found.

3.10 Subroutine MACHLQ

Since the shaft horsepower required for propulsion and size of the electric plant have been determined, the weight of fuel, lube oil, potable water, reserve feed water, and diesel oil can

be calculated. These calculations are performed in subroutine MACHLQ. The weight of the variable load liquids is calculated at this point because it is needed to determine the required tankage volume and the volume calculations preceed those for other weights. A flow chart for the subroutine is given in Figure 9.

The equations used to calculate the liquid weights are listed in Appendix D. The equations derived for specific fuel consumption and fuel rate were based on data given in Reference (12) for all but the COGAS plant and from Reference (1) for that plant.

3.11 Subroutine MBSIZE

The only purpose of subroutine MBSIZE is to determine the minimum allowable depth of the machinery compartment. The equations derived for this subroutine were based upon data taken from Reference (14) and are listed in Appendix D. The flow chart for the subroutine is given in Figure 10.

It was determined that the only critical dimension of the machinery box was depth. This is due to the manner in which the volumes for machinery systems were broken down for estimating purposes. The machinery box as defined for the program contains the volume for all machinery systems except uptakes, shaft alleys, maneuvering related spaces (steering room), and ventilation spaces (fan rooms). The machinery box would therefore contain all of the following spaces:

boiler and firerooms	auxiliary machinery spaces
reactor spaces	electrical generator rooms
engine, motor and gear rooms	switchboard spaces
combined machinery spaces	pump rooms

EPLANT SUBROUTINE FLOW CHART

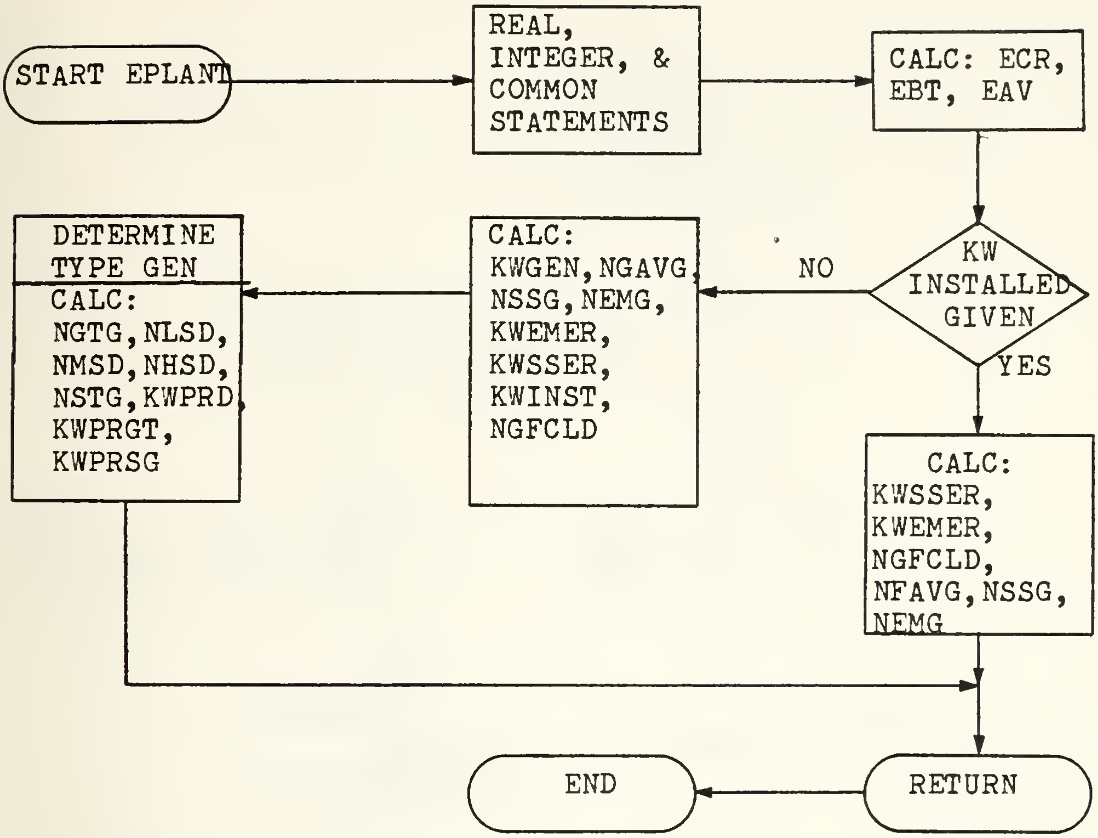


Figure 8

MACHLQ SUBROUTINE FLOW CHART

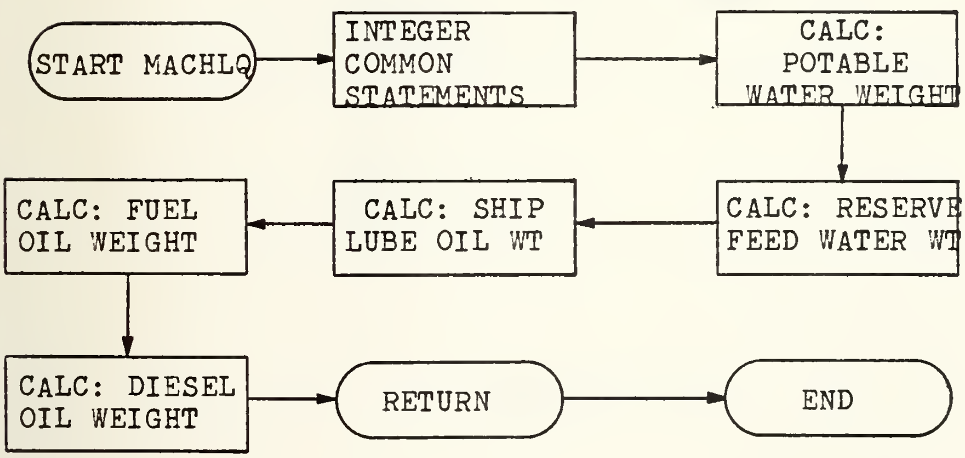


Figure 9

MBSIZE SUBROUTINE FLOW CHART

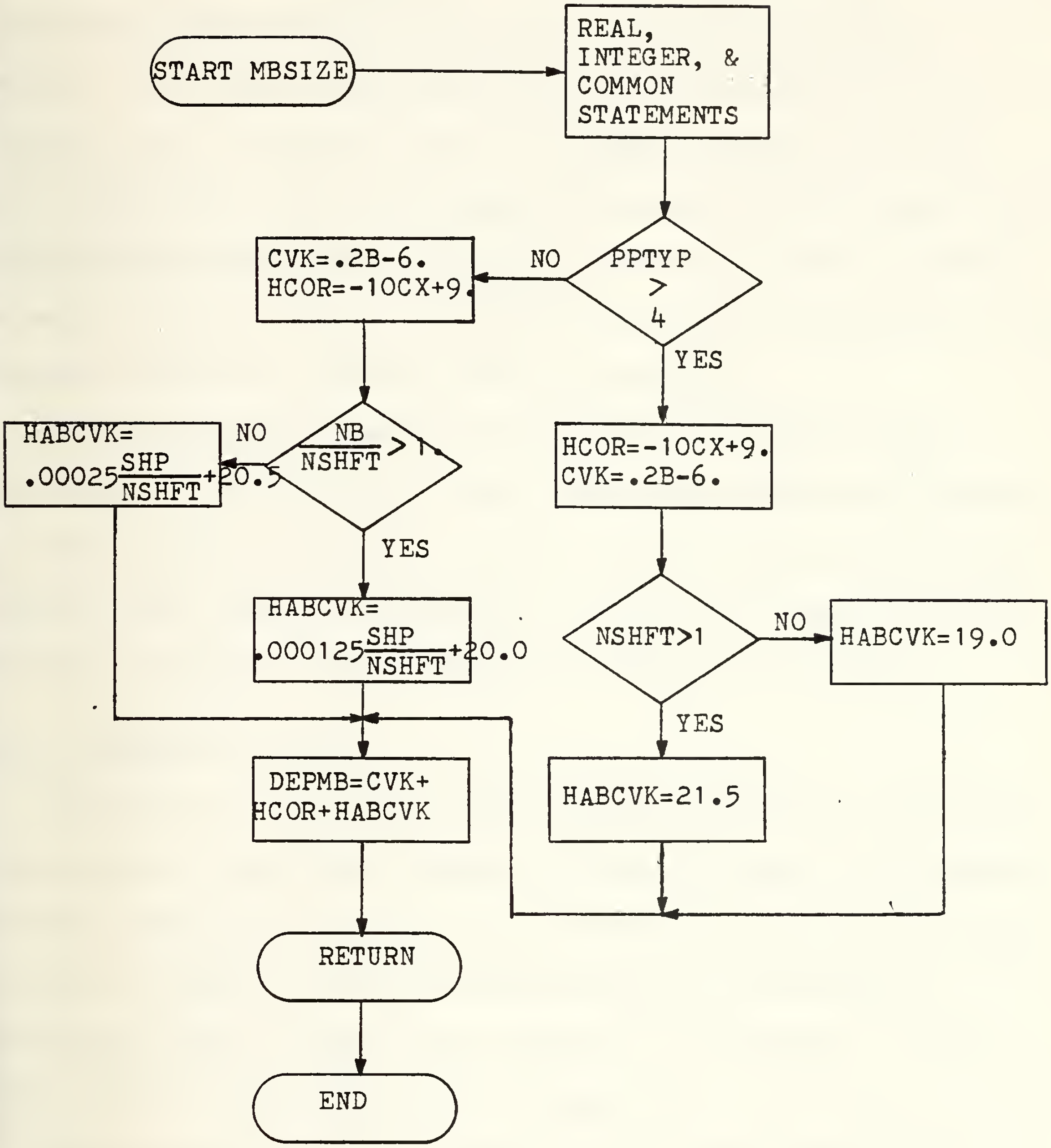


Figure 10

The volume routine estimates one volume to include the above functions. It would be up to the arrangements engineer to divide the volume allocated into the appropriate machinery spaces. Because of the large volume which would be associated with the machinery box, it was felt that the longest length requirement could always be met by appropriate arrangement of other functions within the machinery box. Similarly, it was felt that the beam selected for the ship by subroutine UWDIM would be adequate for the machinery box and no minimum beam is estimated.

Results using the machinery box concept described above were found to be very good. Since most warships contain primarily the same types of equipments, but not always located in the same spaces, a much better correlation for the total volume for these functions could be attained than for individual functions.

3.12 Subroutine VOLUME

Most of the U. S. Navy ships of recent design are considered volume rather than weight limited. Because of this it is important that the synthesis model determine a balance between required and available volume as well as between weight and displacement. Subroutine VOLUME performs this function in the model. A flow chart for this routine is shown in Figure 12.

Since dimensions of the hull below the load waterline are determined in subroutine UWDIM, only the sheer line, deckhouse volume, and the length of raised deck, if any, remain to be determined to define the volume available in the ship. The enclosed volume of the hull and deckhouse will be completely determined by these variables.

VOLUME SUBROUTINE FLOW CHART

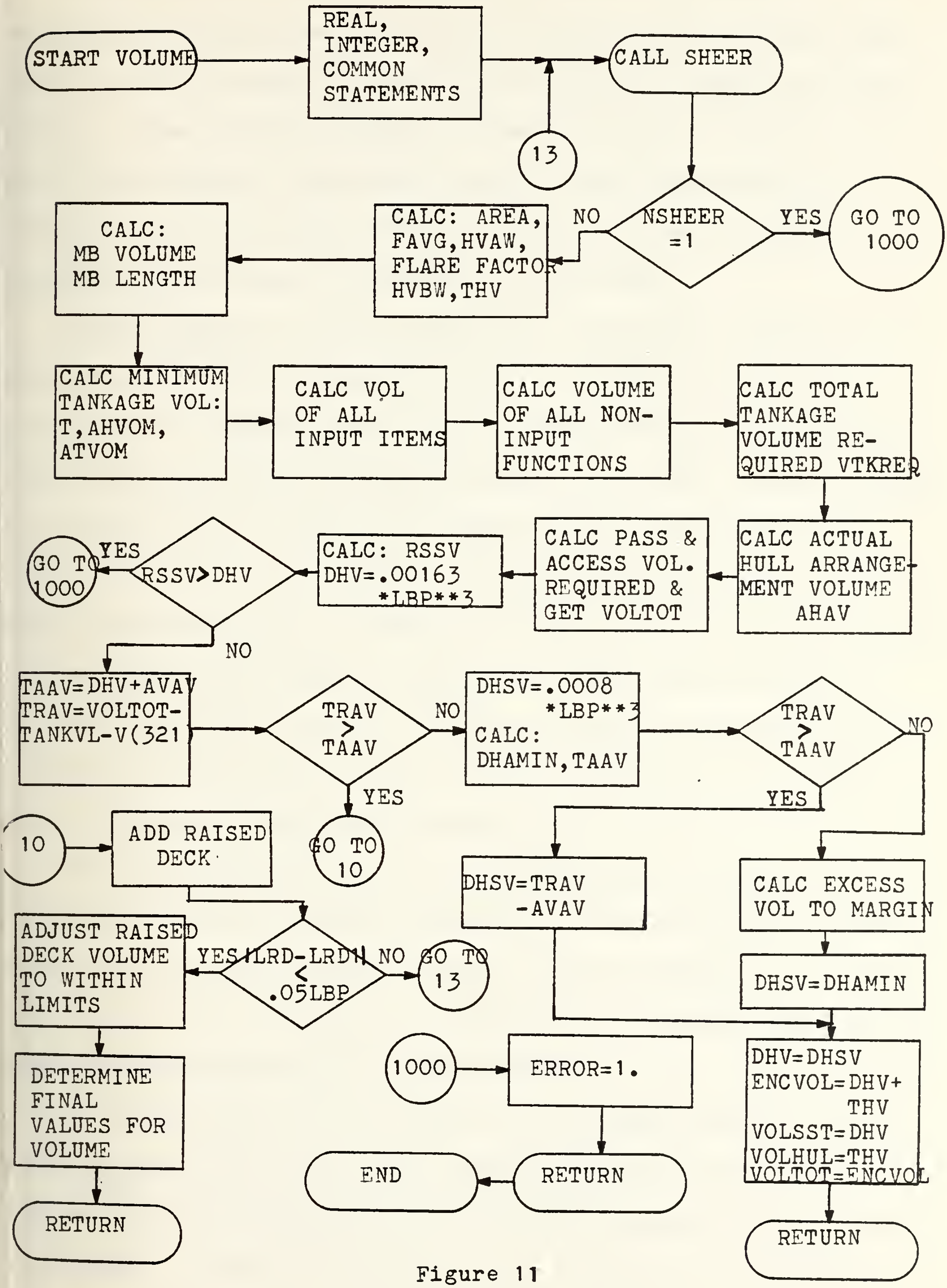


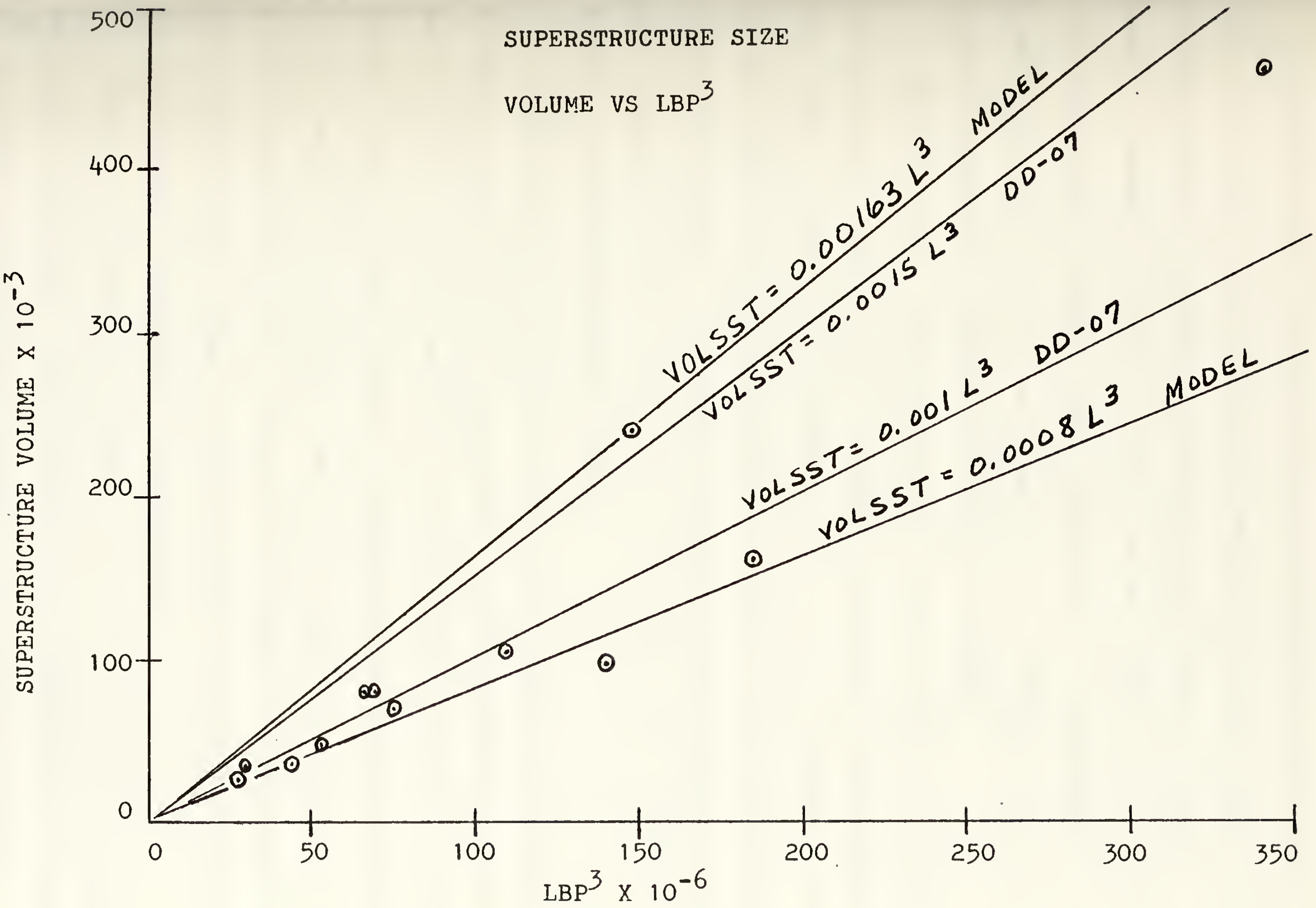
Figure 11

Deckhouse volume is constrained primarily by stability considerations and by external deck area requirements. If the deckhouse becomes too high, it may not be possible to make the vessel stable. Also a certain amount of free deck area is required in nearly all designs, restricting the horizontal spreading of the deckhouse. At the other extreme, the ship may have excessive stability if too small a deckhouse is installed.

These deckhouse volume restrictions have been included in the model by restricting deckhouse size to be within the limits of past practice. Both an upper and a lower limit are placed on the size of the deckhouse as shown in Figure 12. Upper and lower limits of $0.00150 \times L^3$ and $0.001 \times L^3$, respectively, are used in the Navy's destroyer model (DD-07). The model described here uses upper and lower limits of $0.00163 \times L^3$ and $0.0008 \times L^3$, respectively. The new limits were chosen because they can be seen in Figure 12 to bound data for 11 ships in the data sample as compared to only 4 ships for the limits as used in DD-07. The deckhouse volumes shown in Figure 12 do include uptakes.

The volume in the hull is also estimated in VOLUME. The underwater volume is already available. The first step in determining the above water hull volume is the development of an acceptable sheer line. This step is performed by subroutine SHEER and is discussed in conjunction with that routine.

Once the sheer line and with it the average freeboard have been estimated, the above water volume is found by multiplying the area of the waterplane by the average freeboard and by a factor to account for flare. The total volume in the hull is the sum



SUPERSTRUCTURE SIZE
VOLUME VS LBP³
VOLSST = 0.00163 L³ MODEL
VOLSST = 0.0015 L³ DD-07
VOLSST = 0.001 L³ DD-07
VOLSST = 0.0008 L³ MODEL
SUPERSTRUCTURE VOLUME X 10⁻³
LBP³ X 10⁻⁶
0
100
200
300
400
500
50
150
250
350

Figure 12

of the above and below water volumes.

The total hull volume includes the volume to the main deck only. The hull volume cannot be reduced below this size but a raised deck can be added to increase the volume of the hull. The model is somewhat limited in that the most that can be added is one raised deck, however, this has proven to be adequate in synthesizing ships from the data base. The deckhouse size can be varied somewhat to change the available volume.

Required hull volume is broken down into three categories. These are the machinery box, tankage volume and arrangements volume. The object of subroutine VOLUME is to alter the available volume so that there is sufficient space for each of the three categories of required volume. The model assumes that all tankage volume and the machinery box volume are in the hull. The deckhouse contains only arrangements volume.

The machinery box size is the first category estimated. This volume is found in one of three ways. The machinery box volume may be found from the estimating relationships provided in Appendix D, or it may be input directly through the input array for volumes, or the machinery box length, beam, and depth may be input in the problem specifications. Machinery box volume is subtracted from the available hull volume to the main deck leaving a volume which can be used for tankage and arrangements.

Some of the remaining volume cannot be used for arrangements because of hull shape. The next step is to estimate the fraction of the remaining volume that can be used only for tankage. This is the minimum tankage volume for the ship. If less tankage

is required for the liquids that must be carried, the excess volume must be used for voids or cofferdams since it cannot be converted into machinery box space or arrangements volume. If more tankage is required than this minimum, some of the arrangements volume must be used for tankage.

The relationships used in the model for flare factor and tankage volume fraction are the same as those used in Reference (8). These relationships were originally taken from work done on the Navy destroyer model.

The weights of all the liquids which must be carried are calculated in subroutine MACHLQ. In VOLUME, these weights are converted to volumes and added together. The volumes required for liquid stowage and other tankage are added together to determine the total tankage volume required. The required total tankage is then compared to the minimum tankage volume to determine the amount of arrangements volume, if any, that is required for tankage.

All of the volume remaining in the hull after tankage volume and machinery box volume have been subtracted can be used for arrangements. The entire superstructure volume is also available for arrangements.

The total arrangements volume available must be compared to the volume required for all the ship's functions plus the volume due to the specified input. The volume required for ship's functions, such as stores, living and maintenance, are estimated in the model based on past practice. The estimating relationships developed for all volumes are given in Appendix D. Volumes are

either input of calculated for all of the appropriate functional groups of Appendix C.

Data was obtained for the volume relationships from References (21) and (22) and from class notes from M.I.T. Course 13.71. The following ships formed the data base from which the volume relationships were developed:

FF-1006	CG-26	DDG-2
FF-1033	DL-2	FFG-7
FF-1037	DL-1	DD-963
DD-692	CGN-35	
DD-931	CGN-9	

All of the required volumes are summed to determine the total required volume. This volume is then compared to the available arrangements volume in the hull and superstructure.

Comparisons are made in the following order. First, the arrangements volume required to be located in the deckhouse is compared to the volume of the largest allowable deckhouse. If the required volume exceeds that available, the design is infeasible and an error message is printed and the ship length is increased by 10 feet to provide a larger superstructure. Next, the total required arrangements volume is compared to the total available volume. If the required volume is the smaller, the deckhouse size is decreased. The deckhouse size used is either the size which balances the volume requirements or the smallest allowable deckhouse size or the volume required to be in the deckhouse, whichever is greatest. Should the total required volume exceed that available a raised deck is added.

The length of raised deck is determined by an iterative procedure. On each iteration the area required to be included in the raised deck is computed and the relationships provided by Reference (8) are used to convert the area to a raised deck length. The curve developed in Reference (8) is based on the main deck of a 378' Coast Guard Cutter and is considered to give satisfactory results for Navy ships. Since the geometry of a cutter closely resembles that of naval combatants (C_{wp}, L/B, B/H, C_p, C_x, etc.), the area distribution with length at the main deck level can be expected to be approximately the same. The iteration continues until two successive iterations fall within 5 percent of the length of the ship or until twenty iterations is reached. In the latter case the design is ruled infeasible.

If the raised deck length lies between 0.4 and 0.6 times the length of the ship, the raised deck is extended to 0.6 times the length of the ship.

As mentioned before, all of the volume estimating relationships were developed using the Navy ships in the data base, however, the general procedure used for the VOLUME subroutine was taken from Reference (8).

3.13 Subroutine SHEER

Subroutine SHEER selects an appropriate sheer line by specifying the freeboard at the forward perpendicular, amidships, and at the after perpendicular. This sheer line must satisfy a number of criteria.

First, there must be sufficient depth amidships to accommodate the engine room. The depth amidships must also be sufficient

to insure adequate structural strength. A minimum value of L/16 is used.

The next criterion which must be satisfied is adequate freeboard at the forward and after perpendiculars. Navy derived formulas were used. These formulas give the minimum acceptable freeboard based on a deck wetness criterion.

Once independent determinations of freeboard at the forward and after perpendiculars and at amidships are made, a check is required to insure that a reasonable sheer line can be drawn between the three. Reference (8) indicates that data was obtained from past designs and from standard merchant ship sheer curves. This data was nondimensionalized by subtracting the freeboard amidships from the other freeboard values and then dividing by the length of the ship.

The sheer line is assumed to be practical if the forward sheer fraction lies between 0.01 and 0.03 and the after sheer fraction lies between 0.001 and 0.0075. If this is not the case, one or more of the freeboard values is adjusted until the criterion is satisfied.

If a raised deck is added to the hull, a new sheer line is calculated. It is assumed that the required freeboard of the main deck at the forward perpendicular can be one deck height below that required by the deck wetness criterion. This will result in a flattened sheer line as is common for raised deck vessels.

A flow chart for this routine is shown in Figure 13. Additional details of subroutine SHEER may be found in Reference (8).

SHEER SUBROUTINE FLOW CHART

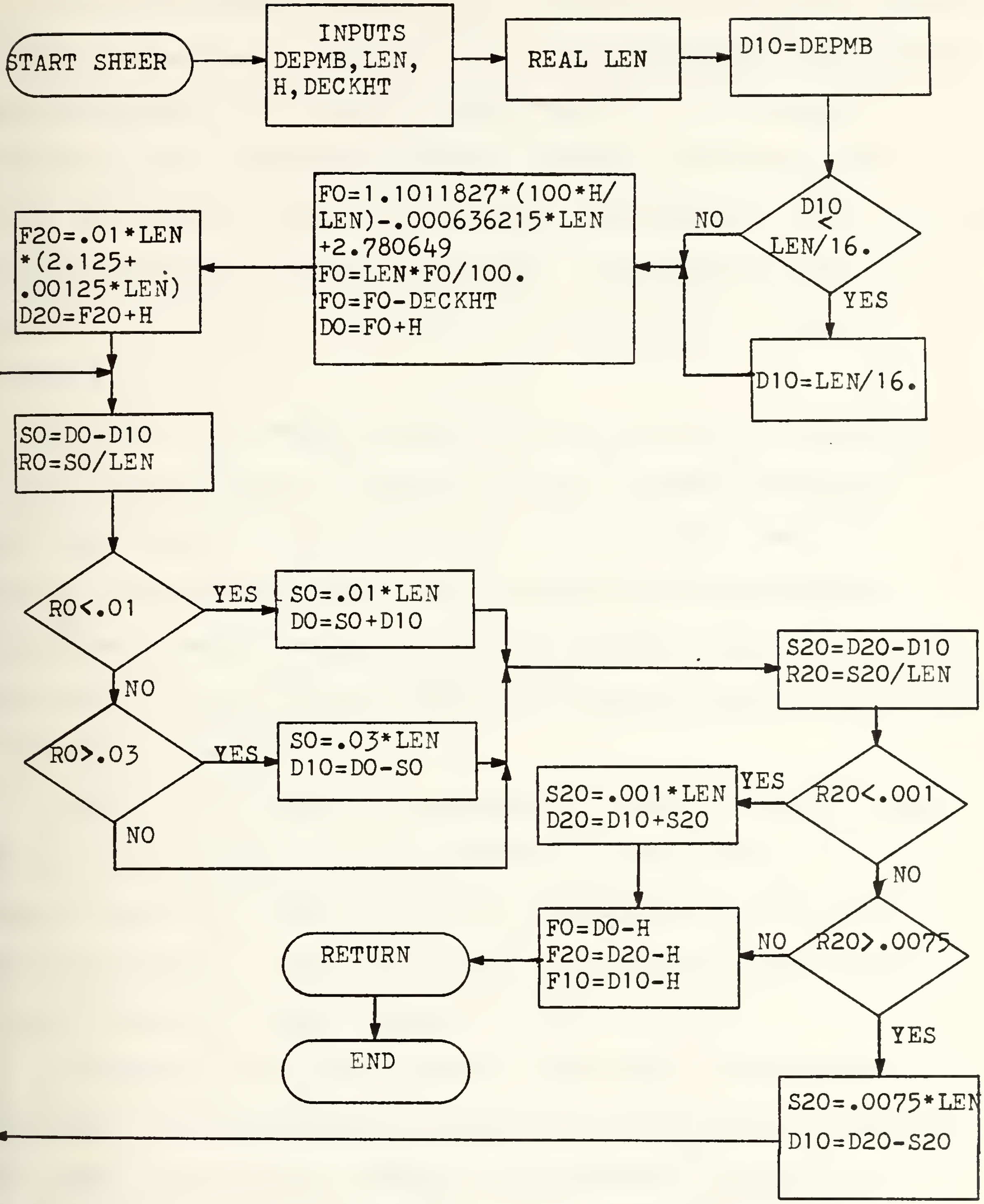


Figure 13

3.14 Subroutine WEIGHT

Subroutine WEIGHT estimates the individual BSCI weight groups for the ship so that a balance can be made between full load weight and displacement. The BSCI was used instead of the currently adopted Ship Work Breakdown Structure (SWBS) of Reference (20) due to the fact that most of the weight data available was in the BSCI form and conversion of ships from SWBS to BSCI listings was considered the simplest. A flow chart for this routine is shown in Figure 14.

Several of the weights required have already been calculated or were given as input. Calculated weights include the liquids which were found in subroutine MACHLQ and the input items calculated in subroutine SPAYLD. Most communications and control weights and armament weights are given as input. The weight groups noted refer to the Modified NAVSHIPS Hull Group Weight Classification as given in Appendix C.

Also given as input are the weights of cargo, aircraft, ammunition, aircraft fuel, and other special payload items. All other weights which are a part of the full load weight are estimated in subroutine WEIGHT. All weights input or calculated are presented at the three digit weight breakdown level.

All weight data, used to develop the weight estimating relationships which are given in Appendix D, was taken from Reference (4). This reference is a complete compilation of weight data for the ships of the weight data base. The original source of all weight data was the weight breakdown sheets prepared for each

WEIGHT SUBROUTINE FLOW CHART

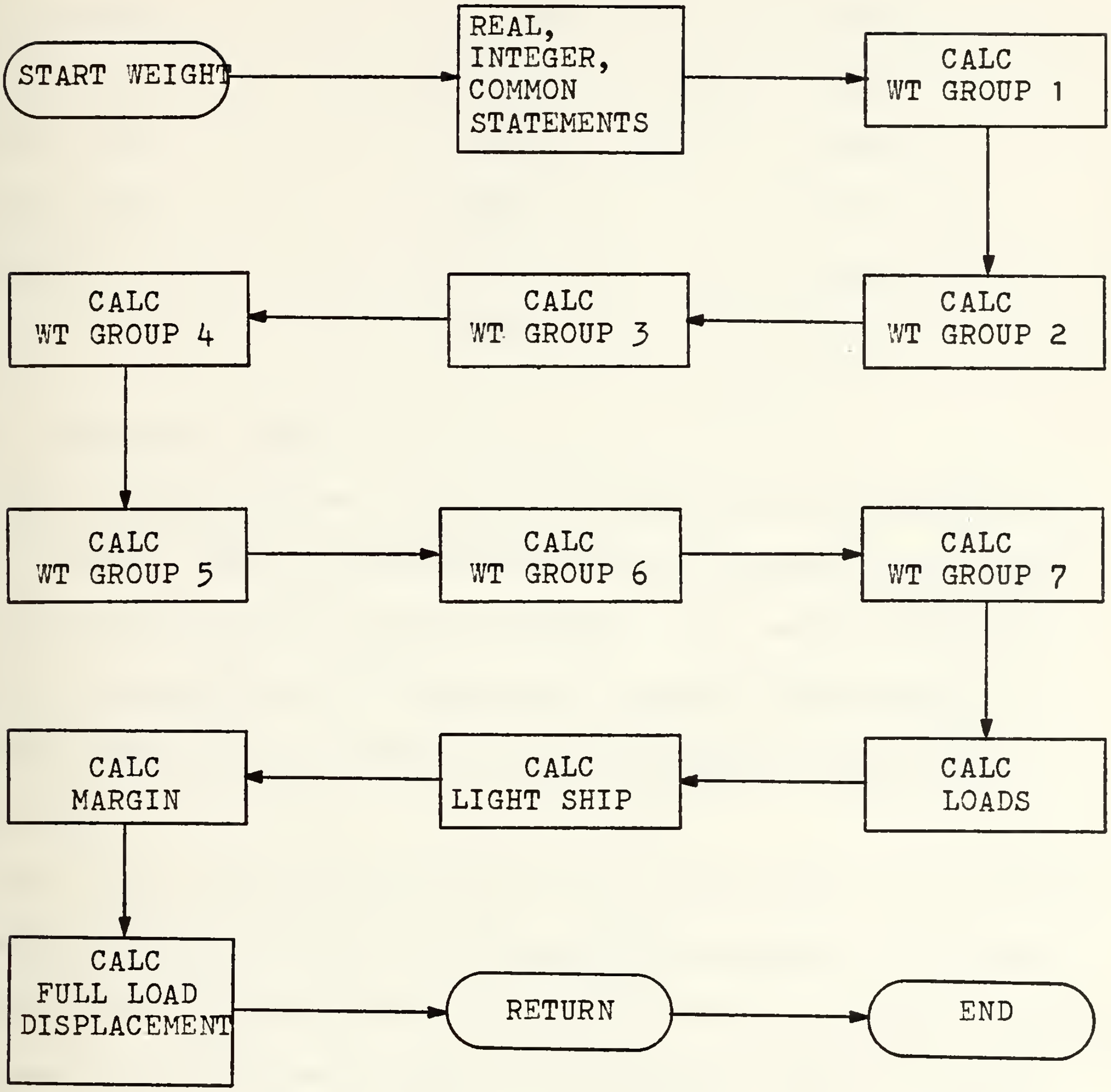


Figure 14

design. The ships used in the weight data base are:

FF-1006	DD-445	CG-9
FF-1033	DD-692	CG-16
FF-1037	DD-931	CG-26
FF-1040	DD-963	CGN-25
FF-1052	DDG-2	CGN-35
FFG-7	DL-1	CGN-36
	DL-2	CGN-9

3.15 Subroutine VRTCG

The vertical center of gravity of the ship is estimated in this routine. Since the designer has some latitude with regard to the location of the center of gravity, the value calculated by this routine should be viewed as a feasible rather than as the best value. A flow chart for the subroutine is given in Figure 15.

The effect that the vcg has on the design can be investigated by using different values of free surface correction. The free surface correction is added to the KG. Therefore, either a positive or a negative value can be used to represent a shift in the KG location.

Subroutine VRTCG estimates a center of gravity for each 3-digit weight group. The vcg for each input item is calculated from input data. The vcg for each non-input function is estimated from the equations provided in Appendix D. The ships used as a data base for estimating the vertical centers are listed below:

FF-1037	DDG-2
FF-1040	CG-26

VRTCG SUBROUTINE FLOW CHART

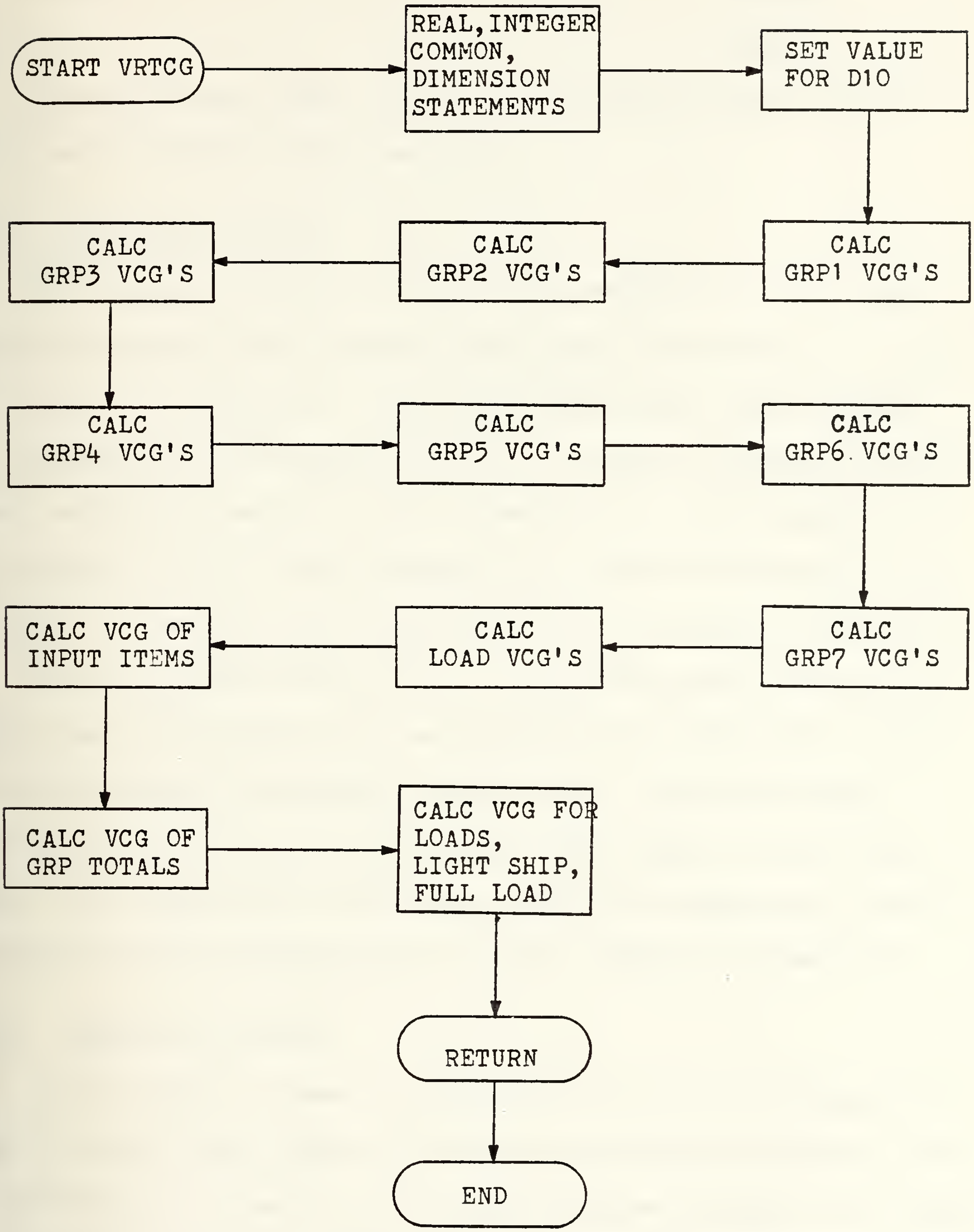


Figure 15

FF-1052	CGN-25
FFG-7	CGN-35
	CGN-9

This data base spans a wide range of ship sizes and gives very good predictions for the vcg's.

3.16 Subroutine FNCGRP

The primary function of subroutine FNCGRP is to place the weights calculated for the BSCI groups into the functional groups as defined in Appendix C. Once the weights have been assigned to the appropriate functional group, a volume and weight will have been assigned to each group and a density for each function can be obtained. All of these values will be printed as part of the output. A flow chart for subroutine FNCGRP is given in Figure 16.

This subroutine functions in a straight-forward manner by taking each functional group and obtaining the associated weight and then density as defined in Appendix C. For those weight groups which are listed as applying to more than one functional group, the weights are proportioned among the appropriate groups according to the equations given in the listing of Appendix E.

3.17 Subroutine SEASPD

This routine is based on the work reported in References (18) and (19) and is the identical subroutine as used in Reference (8). In References (18) and (19) a computer program is given for computing the average sea speed. This computer program was altered by dropping the option to use a bow sonar dome and by deleting the read and write statements. The program was also rewritten in ASA

FNCGRP SUBROUTINE FLOW CHART

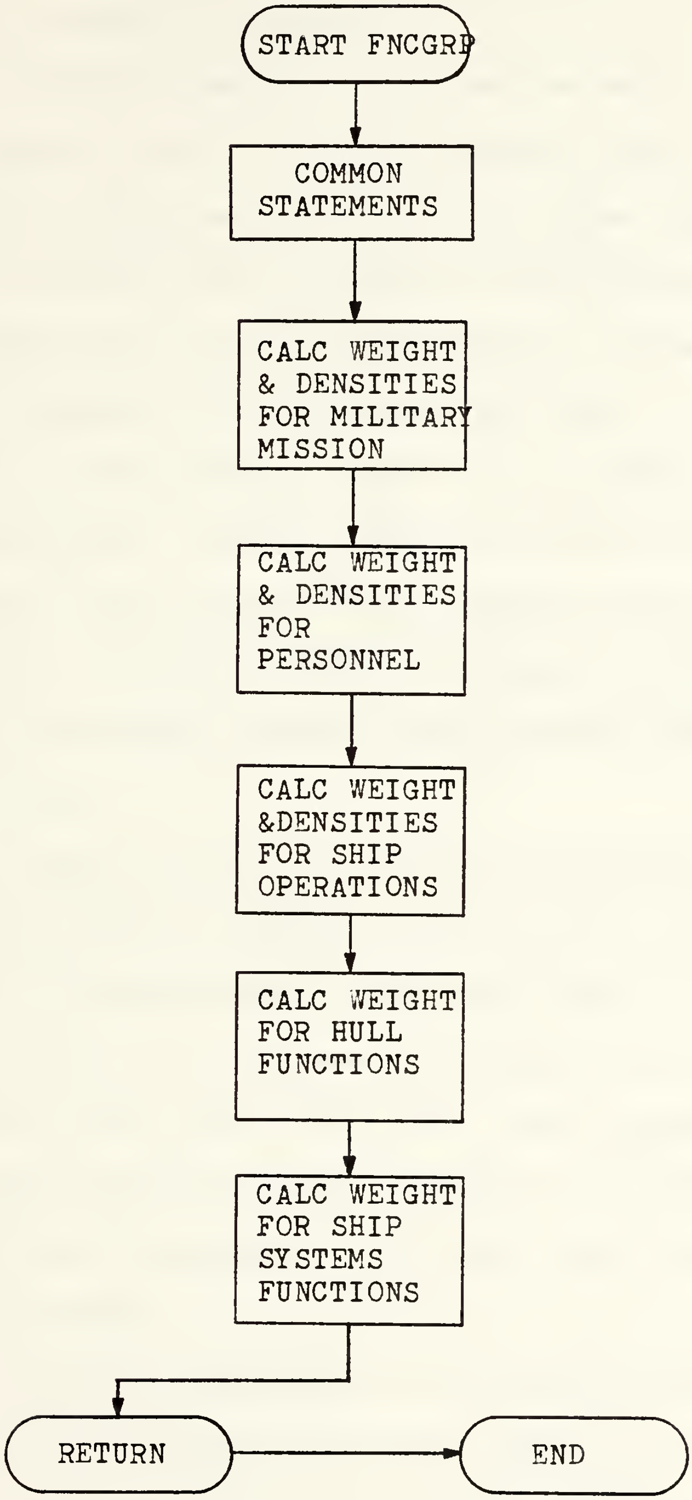


Figure 16

standard FORTRAN. Except for these changes, subroutine SEASPD is the computer program developed in the references. A flow chart for this routine is shown in Figure 17.

Briefly, the routine assumes: (1) that the ship is operating in the North Atlantic Ocean over a long period of time; (2) that it is steaming into head seas one half of the time; and (3) that the remainder of the time (when steaming at other headings) it is not forced to reduce speed due to ship motions. The part of the time the ship is steaming into head seas, its speed will be limited by the sea state. In the routine this is simplified to a single sea state limited speed. The remainder of the time the ship is assumed to be able to make its maximum sustained speed. The percentage of the time the ship is limited in speed is estimated based on average wave heights in the North Atlantic Ocean and on ship characteristics.

The average speed at sea is calculated assuming that the vessel will travel at its maximum sustained speed whenever it is not limited in speed by the sea state. When the vessel is steaming at headings other than into head seas, its speed is not limited. This is assumed to be one half of the time. When steaming into head seas its speed will be limited only part of the time. Both the limiting speed and the percentage of time that it applies are calculated in SEASPD.

This routine has been included to indicate the effect that changes in the vessels characteristics will have on its seakeeping ability. The many assumptions made in deriving the average sea speed limit the usefulness of the speed predicted. However, the

SEASPD SUBROUTINE FLOW CHART

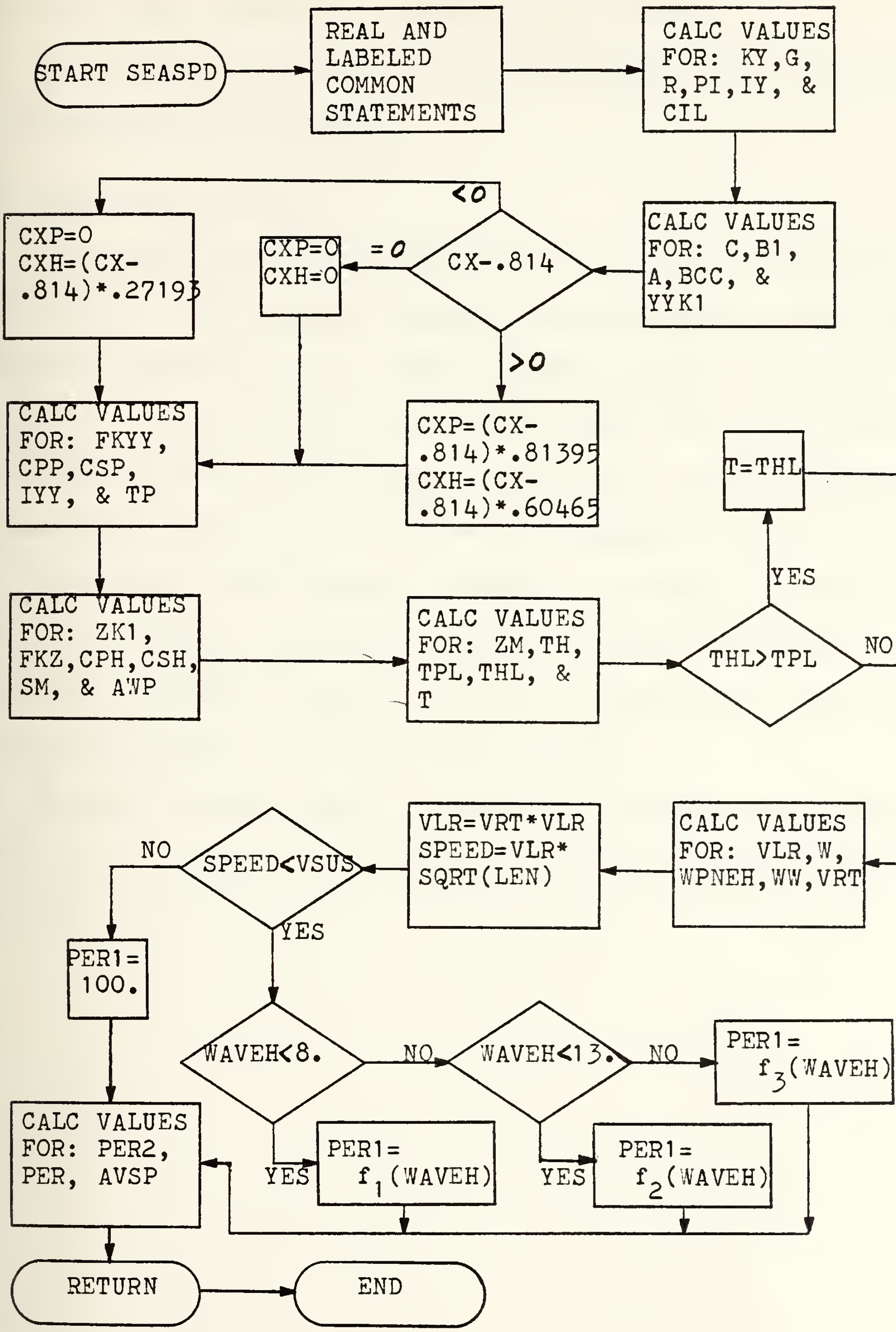


Figure 17

speed calculated can be used to compare two designs to decide which will give the better seakeeping performance.

For additional details of this routine the reader should refer to References (18) and (19).

3.18 Subroutine OUTPUT

All program output is printed by subroutine OUTPUT with the exception of error messages and some default options in the MAIN program. A simplified flow chart for this routine is shown in Figure 18. Subroutine OUTPUT is used to print the input data and the output generated to the degree specified by problem specifications 72 and 73 which are defined in Appendix A.

Subroutine OUTPUT consists primarily of print and format statements. Some calculations are made but only to convert previously calculated values to a desired output form, such as, determining several ratios which are output.

The only decision points used are to determine the amount of output to be printed. These decision points are shown in the flow chart.

OUTPUT SUBROUTINE FLOW CHART

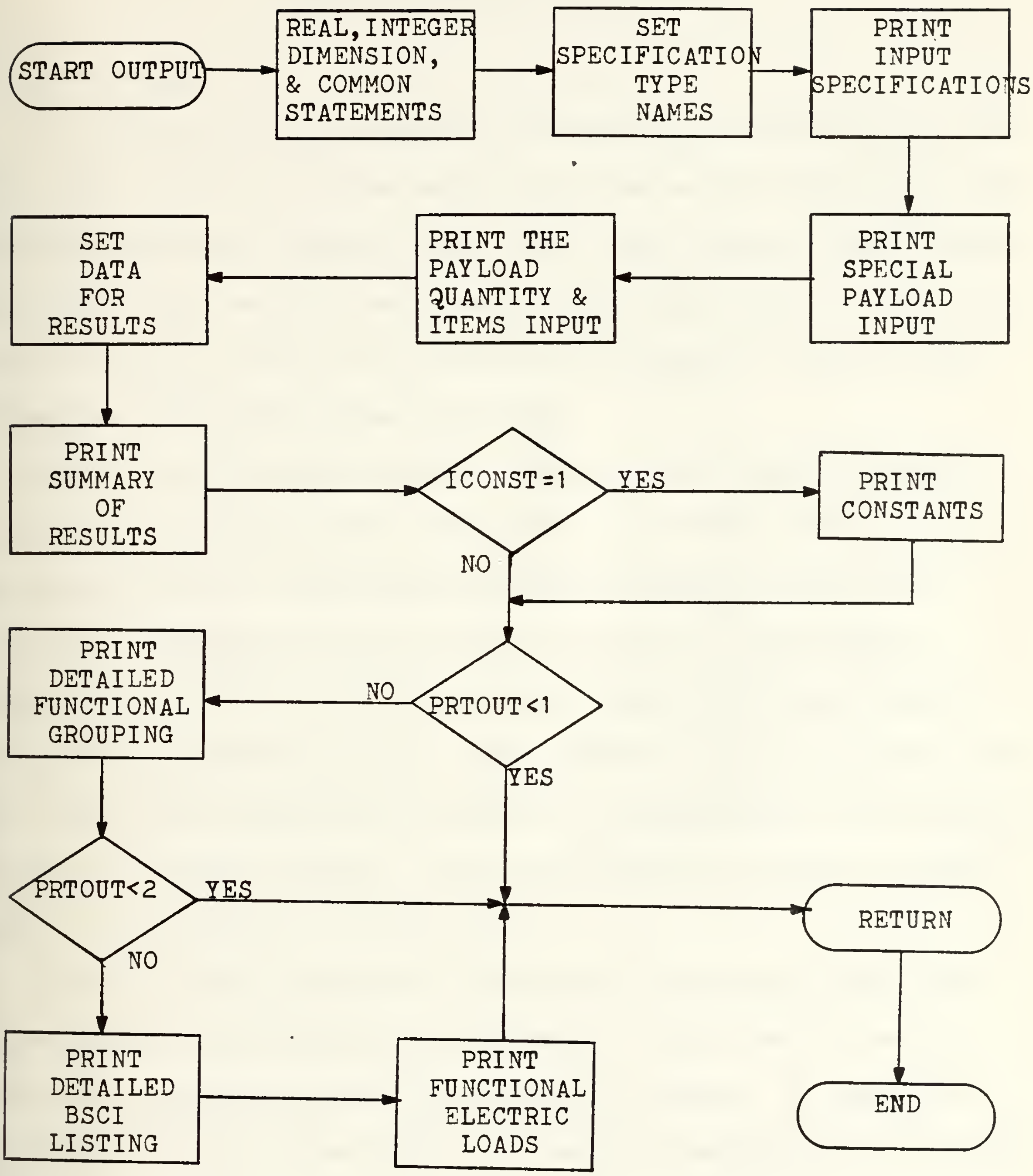


Figure 18

CHAPTER 4

RESULTS OF MODEL APPLICATION

4.1 Introduction

As a basis for evaluating the accuracies and versatility of the model, this chapter provides particular results from using the model to synthesize several surface ships over a wide range of size. Both data sample ships and non-data sample ships were tested. The test runs were made on the IBM 370, model 168, computer located in the Information Processing Center at M.I.T.

Section 4.2 discusses results obtained when using the model as a conceptual design tool. During the conceptual design phase, many combinations of input variables are generally tried before the specific features of the ship are selected. Once specific features, e.g., length, horsepower, individual weight and volume groups, and accommodations, have been selected the model may be used with these known parameters to provide a design update with increased accuracy in overall results. Use of the model to provide a design update is presented in section 4.3.

Since the model allows for the input of specific weight and volume groups and habitability standards, it may also be used as a tool for comparative naval architecture studies. An example of the model used as a comparative tool would be designing the FF-1052 to Soviet design standards. Results of this application and others are presented in section 4.4.

Section 4.5 is provided to give an overall assessment of the results and how they should be interpreted and used.

4.2 Model in Conceptual Phase

A comparison between results produced by the model and the actual ships is given in Table 3. All of the ships compared in this table except for one, the FFG-2, were in the data sample used.

Model predictions of Table 3 are the result of input specifications which assumed the ship designs to be in the early conceptual phase, therefore, the large percentage difference for some of the ships was expected. The only input specifications reflecting the actual ship were:

LBP	Accommodations
VSUS	C_p
Payload Items	C_x
Endurance	Duration
Type Propulsion Plant	Type Electric Plant

The program was allowed to make the standard calculations for all weight and volume groups and to size the propulsion and electric plants. Since the standard calculations built into the model reflect what is probably the "average" ship over the past 20 years, the results for the ships built during the mid 1960's with few special features, e.g., FFG-2, FF-1040, and CG-26, are good for this level of input.

For the ships which differ considerably from the model predictions, special features can be identified to account for the major portion of the difference. For example, if the habitability standards used by the model to predict the FFG-7 and DD-963 were increased from the model standard to current standards, the predicted results would improve.

SHIP	FULL LOAD DISPLACEMENT DATA	MODEL	% DIFF	INTERNAL VOLUME DATA	MODEL	% DIFF	BEAM DATA	MODEL	DRAFT DATA	MODEL	DEPTH DATA	MODEL	KG DATA	MODEL
FF 1003	1770	1647	- 6.9	242397	254181	+ 4.9	37	38.7	12	10.3	28	29.2	14.1	17.1
FFG 2	3412	3400	- 0.4	363583	406118	+11.7	44.2	40.9	14.7	15.8	30.5	30.0	*	16.0
FF 1040	3371	3494	+ 3.6	*	399728	*	44.2	41.0	14.3	16.2	30.5	30.7	*	16.0
FFG 7	3585	3013	-16.0	516452	368999	-28.6	45	39.7	14.4	14.5	30.0	27.2	18.6	16.5
FF 1052	3934	3507	-10.9	481020	402596	-16.3	46.7	40.3	14.9	15.2	29	28.6	16.6	15.6
DDG 2	4525	5577	+23.2	517946	583399	+12.6	48	49.0	15	17.6	25	33.4	17.0	18.3
DD 963	7644	6408	-16.2	1046839	688137	-34.3	55	47.8	18	19.0	42	35.4	22	18.4
CG 26	7828	7720	- 1.4	*	797922	*	54.8	50.7	18.8	20.0	38.4	37.4	19.5	19.2
CGN 9	16294	12680	-22.2	1959652	1599624	-18.4	73.2	65.0	24.3	20.1	46	43.8	*	25.8

Note: In the model predictions above only VSUS, LBP, and payload were specified. The program was allowed to make standard calculations for all unknowns.

*Data Not Available

TABLE 3

COMPARISONS OF CALCULATED AND ACTUAL

CHARACTERISTICS--CONCEPTUAL PHASE

In general, the full load displacement predicted will vary from the actual ship data in the same manner as the internal volume difference varies. As an example, the model prediction for the DDG-2 is approximately 1000 tons more than the actual ship in full load displacement. The volume predicted is also too high by about 66,000 cubic feet. Most of the error in the prediction can be found in weight groups 1, 2, 5, and 6 with over predictions of approximately 500, 100, 100, and 50 tons, respectively. This accounts for about 750 of the excess 1000 tons with the remaining 250 tons spread over the remaining weight groups. Calculations for the weight of groups 1, 5, and 6 are highly dependent upon the internal volume of the ship. When the volume is reduced to near the actual value, as can be seen in the next section, the predictions for these weight groups decrease and a much better prediction is obtained. The excess volume predicted for the ship is the result of the model assigning the freeboard to be approximately 5 feet greater over the length of the ship than the actual freeboard. This 5 foot of freeboard difference accounts almost entirely for the 66,000 cubic feet over prediction. It should be noted that the DDG-2 is probably the most volume critical ship in the data base.

Once characteristics and standards for the ship are selected as the design process continues, these specified features may be input to the model to provide a design updated prediction which would more closely predict the final ship. The results of this application are presented in the next section.

4.3 Model Used to Update Design Predictions

Since the model provides the option of specifying weights, volumes, vcg's, and electrical loads, in addition to accommodating payload changes and habitability standards, it offers the capability to update ship predictions as the design features become fixed. To illustrate the model use to update predictions, Table 4 is provided. In this table the same ships are presented as in Table 3 with the addition of the CGN 25. The inputs to the model for this run were more specific with the following features input:

LBP	Accommodations
Installed SHP	C_p
Payload Items	C_x
Endurance	Duration
Type Propulsion Plant	Type Electric Plant
Habitability Standards	Size Electric Plant
Ammo Weight	Weight Groups 200 & 201

The overall results are shown in Table 4a. It can be noted that the differences between model prediction and ship data are now much less than those of Table 3. These results were expected since the new inputs better define the actual ships.

The results of Table 4a were improved over those of Table 3 mainly because installed SHP, habitability standards, and electric plant size were input. In a few instances the percent difference for full load displacement was then changed from a minus value to a plus value or vice versa. One of the reasons for this occurring is that the SHP and installed KW were input for the results of Table 4, but were estimated by the program based on VSUS and other variables

SHIP	FULL LOAD DISPLACEMENT DATA	MODEL	% DIFF	INTERNAL VOLUME DATA	MODEL	% DIFF	BEAM DATA	MODEL	DRAFT DATA	MODEL	DEPTH DATA	MODEL	KG DATA	MODEL
FF 1033	1770	1790	+1.1	242397	269488	+11.2	37	39.6	12	10.8	28	29.2	14.1	17.2
FFG 2	3412	3702	+8.5	363583	423274	+16.4	44.2	42.2	14.7	16.7	30.5	31.7	*	16.5
FF 1040	3371	3621	+7.4	*	401777	*	44.2	41.4	14.3	16.6	30.5	31.6	*	16.2
FFG 7	3585	3542	-1.2	516452	493040	- 4.5	45	42.4	14.4	16.0	30	34.0	18.6	18.4
FF 1052	3934	3879	-1.4	481020	435294	- 9.5	46.7	42.0	14.9	16.2	29	30.5	16.6	16.4
DDG 2	4525	4908	+8.5	517946	521413	+ 0.7	48	46.4	15	16.4	25	30.9	17.0	17.4
DD 963	7644	7449	-2.6	1045839	959192	- 8.3	55	54.2	18	19.5	42	42.1	22	21.0
CG 26	7828	8123	+3.8	*	866690	*	54.8	52.1	18.8	20.5	38.4	38.4	19.5	19.7
CGN 25	8519	8751	+2.7	*	906864	*	57.9	56.2	19.1	21.6	42	40.3	22.2	22.0
CGN 9	16294	16230	-0.4	1959652	1950001	- 0.5	73.2	70.0	24.3	23.9	46	43.8	*	27.2

Note: In the model predictions in this table, LBP and payload were specified the same as for Table 3, but also specified were SHP, installed electric plant, habitability standards, ammo weight, and weight of groups 200 and 201.

*Data Not Available

TABLE 4a

COMPARISONS OF CALCULATED AND ACTUAL CHARACTERISTICS--

DESIGN UPDATE

to obtain the results of Table 3. For the ships where the results of Table 3 were within a few percent of the actual full load displacement, e.g., FF-1033, FFG-2, and CG-26, the change in propulsion and electric weights alone could be enough to change the percent difference from minus to plus or the reverse.

For the ship characteristics shown in Table 4a, the results below were noted.

a. The difference between actual and predicted full load displacement varied from +8.5 to -2.6 percent. However, of the 10 ships modeled, 7 of the estimates were within 4 percent of the actual ship displacement.

b. The difference between actual and predicted internal volume varied from +16.4 to -9.5 percent. This result is not as bad as it might seem, since ships which have large differences in volume can still have small differences in displacement. For example, the FF-1052 volume difference is -9.5 percent, but the displacement difference is only -1.4 percent. This result occurs because the volume differences are generally the greatest in the functional areas of passageways and access and tankage (voids). These are not very dense functions and addition or loss of volume in these areas have only a minimal effect on displacement.

c. The largest percent difference in beam was -10 percent. This was for the FF-1052 for which the displacement and volume were also estimated low. In this case the predicted beam would be closer to the actual beam if the displacement and volume were increased.

d. The largest percent difference in draft was +16 percent. This was for the FF-1040 which was also estimated high in displacement by 7.4 percent. If the displacement was estimated lower, then the draft would also be closer.

e. The largest percent difference in depth is +24 percent. However, of the 10 ships modeled, 8 of the estimates were within 5 percent of the actual depth. The ship which differed by 24 percent was the DDG-2 which has an unusually small freeboard.

f. The largest percent difference in KG was +22 percent for the FF-1033. The KG for the other ships was within 5 percent of the actual value.

Detailed results for the major weight and volume groups are given in Tables 4b and 4c. The differences are reasonably small in most areas with the majority of the weight groups being 5 to 10 percent from the actual values. As was the case in the previous section, the primary cause of the difference is related to overall ship volume, i.e., when the predicted ship volume is too low the weights for groups 1, 5, and 6 will generally be low also. This in turn influences the amount of energy required for the ship and affects weight groups 2 and 3 and some variable load items.

From Table 4b it is noted that the predictions for weight group 2, propulsion, are within 12 percent for all ships and within 8 percent for all but the FFG-2 and FF-1040. Because of this, the model predictions for weight group 2 are considered to be very satisfactory when the installed SHP is specified.

The results for weight group 3, electric plant, even with the

SHIP	WTGP1		WTGP2		WTGP3		WTGP4		WTGP5		WTGP6		WTGP7		LOADS	
	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL
FF 1033	601	566	224	232	40	56	43	86	144	188	136	166	40	47	516	448
FFG 2	1117	1136	352	394	117	106	289	274	312	302	274	241	111	132	836	1119
FF 1040	1110	1098	352	390	105	101	150	250	313	319	220	229	98	122	931	1110
FFG 7	1247	1186	255	271	207	167	99	131	412	345	302	260	96	100	834	965
FF 1052	1291	1185	422	456	130	106	294	277	365	351	273	244	145	158	1014	1104
DDG 2	1218	1501	831	786	122	106	176	171	375	408	271	299	258	290	1248	1347
DD 963	3081	2621	767	780	263	248	358	365	708	622	459	450	147	135	1861	2228
CG 26	2356	2579	944	968	221	281	372	450	615	631	425	439	320	351	2575	2424
CGN 25	2992	3026	2325	2390	521	477	398	391	573	591	446	484	389	391	775	1000
CGN 9	6562	6488	3571	3576	754	741	866	710	1028	1078	966	939	958	933	1469	1764

TABLE 4b

DESIGN UPDATE--WEIGHT COMPARISONS

SHIP	MILITARY MISSION VOLUME		PERSONNEL VOLUME		SHIP OPS VOLUME		SUPERSTRUCTURE VOLUME		HULL VOLUME	
	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL	DATA	MODEL
FF 1033	24066	46851	74595	82726	143735	139912	26824	53914	213310	215574
FFG 7	97799	89288	111293	111150	304520	292602	82113	110705	434339	382335
DDG 2	104796	81024	130632	149078	282517	291311	70226	106636	441719	414777
DD 963	163500	159092	194061	164977	689278	635124	211152	241298	835687	717894
CGN 9	602602	611671	447179	461245	909875	877095	458567	550095	1499428	1399907
FFG 2	83383	105252	101000	109122	179200	208901	*	91133	*	332141
FF 1052	109052	107792	116538	109017	255430	218484	*	89200	*	346094

*Data Not Available

TABLE 4c

DESIGN UPDATE--VOLUME COMPARISONS

plant installed KW specified, are on the average about 20 percent from the actual values. Most of the difference can be traced to the results for group 300, electric power generation. This estimating equation may require some modifications. Also, some of the difference is caused by the total internal volume prediction being different from the actual value, since weight groups 302 and 303 are estimated in the program as functions of the internal volume. However, most of the error in the weight group 3 prediction could be eliminated by input of weight group 300 directly into the program once the electric plant has been selected and this weight is known.

The weights for groups 4 and 7 of Table 4b and the volumes for military mission in Table 4c are determined primarily from values input from the payload shopping list. In some cases the predicted values are very close and in other cases the values predicted are off by as much as 100 percent, i.e., weight group 4 for the FF-1033. There are two reasons for the errors which occur. First, some of the data in the shopping list may need modification to reflect better the values required on existing ships. Second, the payload list input to the program for each ship may have been incorrect. In a few instances data on the exact payload for the ship was not available and an estimated payload was used, e.g., number of rounds of ammunition. In general, the results for weight group 7 were closer than those for group 4.

The model prediction for the total weight of load items is in most cases 10 to 20 percent too high. One reason for this is that the model seems to consistently predict the fuel required too high by the same 10 to 20 percent. This would not account for all of the

difference, but would account for a significant portion, i.e., up to 50 percent. The calculations for fuel and diesel oil should be reviewed and could be improved upon.

As a next iteration, more of the individual weights and volumes could be input than was done to obtain the results of Table 4 and even greater accuracy would be expected.

Reference (8) presents a comparison between the actual ship, DD-07, and the Coast Guard Cutter Model for the Navy's Patrol Frigate (FFG-7) design. These results are presented in Table 5 along with the model predictions of Table 4. The input specifications for all of the model predictions of Table 5 are to nearly the same level of detail. It should be noted that the actual ship data and the model prediction reflect an installed electric plant of 4 diesel generators while the Cutter and DD-07 predictions reflect only a 3 generator plant as originally planned. The model results compare favorably with DD-07 and Cutter output.

The results presented in Reference (3) compare actual full load displacement to CODESHIP model results for a number of ships over a wide range of sizes. Six of these same ships have also been predicted by the current model. A comparison between the results of the two models is given in Table 6. As was the case above, the level of input is approximately the same. The model generally gives better results than CODESHIP when predicting ships in this size range. However, the CODESHIP model is built on a data base which includes ships which range in size from small patrol craft to aircraft carriers. The CODESHIP model is intended to synthesize ships of all sizes and types for conceptual analysis and for comparing

TABLE 5

COMPARISON OF MODEL RESULTS TO THE ACTUAL SHIP,

C.G. CUTTER MODEL, AND DD07 MODEL

FOR THE FFG-7 DESIGN

	LBP ft	BEAM ft	DRAFT ft	DO ft	D10 ft	D20 ft	DAVG ft	DISP. tons
SHIP	408	45.0	14.4					3585
MODEL*	408	42.4	16.0	33.9	25.5	26.7	35.2	3548
DD07	405	46.7	15.3	41.0	34.0	34.8	35.3	3766
CUTTER	405	46.0	15.3	41.1	28.9	29.3	31.0	3706

WEIGHTS

	SHIP	MODEL	DD07	CUTTER
WTGP 1	1247.3	1185.7	1331.2	1199.6
WTGP 2	254.6	270.6	240.0	258.0
WTGP 3	207.0	166.5	156.6	211.2
WTGP 4	99.3	131.3	70.7	70.7
WTGP 5	411.6	345.4	381.3	317.5
WTGP 6	302.2	260.4	238.0	333.8
WTGP 7	96.1	99.8	85.7	85.7
WTLSHIP	2618.1	2510.7	2503.5	2476.5
LOADS	833.8	965.3	1100.5	1070.2
MARGIN	133.5	123.0	162.9	161.0
	3585.4	3548.0	3766.9	3707.7

* Model prediction has 8.5' raised deck for 387 ft.

TABLE 6

COMPARISON OF MODEL AND CODESHIP RESULTS FOR

FULL LOAD DISPLACEMENT

SHIP	DATA	MODEL	MODEL % Diff	CODESHIP	CODESHIP % Diff
FF 1040	3371	3621	+7.4	3643	+ 8.1
FFG 2	3412	3702	+8.5	3698	+ 8.4
FF 1052	3934	3879	-1.4	3991	+ 1.4
DDG 2	4525	4908	+8.5	5269	+16.4
CG 26	7828	8123	+3.6	8700	+11.1
CGN 25	8519	8751	+2.7	8262	- 3.0

cost and technical results not necessarily accurate in absolute values.

4.4 Model as a Comparative Tool

Another possible use for a versatile design model would be as a tool for comparative naval architecture studies. In Reference (11), Captain Kehoe suggests differences in design standards for warship design between the Soviet and U. S. Navies. Applying the suggested standards to the FF-1052, but keeping the payload, installed SHP, and accommodations of the originally designed ship, the new ship was synthesized to the standards listed in Table 7. The results for weight and volume (Table 7) indicate a smaller, faster, and denser ship would be realized at the expense of reduced habitability, endurance, maintenance, and access. This result is as expected and seems to be a reasonable estimation of the redesigned ship.

The reduced habitability standards can be input using the miscellaneous specifications described in Table 18 of Appendix A. To reduce the habitability standards by 40 percent of conventional U. S. practice, a value of 0.6 could be entered for the habitability related coefficients of Table 18. The reduced volumes for the bridge, offices, machinery box, ventilation, maintenance, and passageway and access were directly input to the program by taking the appropriate percentage of the model predicted FF-1052 volumes. The reduced deck height and endurance were directly input to the program.

As a second example, the FF-1052 was modeled as if it had

TABLE 7

FF 1052 TO SOVIET DESIGN STANDARDS

FUNCTIONAL GROUP CHANGES

Military Mission (Payload)	FF-1052 as ORIGINALLY DESIGNED
Personnel	Reduced habitability space by approx. 40%
Ship Ops	Reduced bridge and office space Reduced machinery box volume by 20% Reduced ventilation space & weight Reduced maintenance space by 50% Reduced passageway & access by 30% Reduced between deck height to 8 ft. Changed endurance to 3500 miles

SHIP COMPARISONS

WEIGHTS (tons)

	DATA	FF 1052 CALC BY MODEL	FF 1052 TO SOVIET STANDARDS
WTG1	1291	1185	1022
WTG2	422	456	454
WTG3	130	106	101
WTG4	294	277	271
WTG5	365	351	293
WTG6	273	244	204
WTG7	145	158	158
Loads	1014	1104	908
Full Load	3934	3881	3411

VOLUMES (cu ft)

	FF 1052 CALC BY MODEL	FF 1052 TO SOVIET STANDARDS
Military Mission	107792	96022
Personnel	109017	78610
Ship Ops	218484	180415
Total	435293	355046
Superstructure	89200	59270
Hull	346094	304178

been designed to estimated Soviet mission requirements and design practices. The changes made to produce the Sovietized FF-1052 were taken from Reference (11) and are given in Table 8. These changes in standards were also handled by directly inputing appropriate weight and volume groups and the new payload list and problem specifications. The resulting ship characteristics are given in Table 9. The model predicts the Sovietized FF-1052 to be even lighter than the ship of the previous example. This result seems reasonable due to the greater impact on the ship of the FF-1052 payload as compared to the Sovietized payload with twice as many payload items. The SQS 26 Sonar and 5"/54 Rapid Fire Gun are much higher impact items than the individual components of the Sovietized weapon suit.

The model may also be of assistance in estimating the characteristics of ships for which little data is available. As an example of the model used in this manner, the Soviet "Kara" Class CG was estimated. Inputs for the model were those given in Reference (11) with the Soviet weapons suit being input as comparable items from the payload shopping list. The input for the Kara run is listed at the end of the computer listing in Appendix E. The estimated Kara Class characteristics are given in Table 10.

As a final comparative example, the FFG-7 was synthesized using design standards characteristic of the high performance ships, i.e., hydrofoils and surface effect ships. The inputs to the model were the same as those the FFG-7 presented in earlier results with the following changes:

a. length was not specified (L/B and B/H specified);

TABLE 8

SOVIETIZED FF-1052

Functional Group	Changes
Military Mission (Payload)	Changed Major Payload Items to: 5"/54 Lw Gun MK 22 Tartar 2 Harpoon Canisters MK 74 GMFCS MK 87 GFCS SPS-52 Radar ASMD Suite 2 MK 32 T/T D/M Redeye ASROC Launcher 2 CIWS Helo Hangar VDS SQS 23 Sonar
Personnel	Reduced habitability space by approx. 40%
Ship Ops	Reduced bridge and office space Reduced machinery box volume by 35% below standard program value for same horsepower Reduced ventilation space and weight Reduced maintenance space by 50% Reduced passageway & access by 30% Reduced between deck height to 8 ft. Changed endurance to 3500 miles Increased speed to 33 knots Increased number of shafts to 2 Increased number of boilers to 4

TABLE 9

SOVIETIZED FF-1052 CHARACTERISTICS

Characteristic	Value
LBP	420 feet
Beam	39.6 feet
Draft	14.6 feet
Depth @ station 0	39.9 feet
Depth @ station 10	27.3 feet
Depth @ station 20	27.8 feet
C_p	.577
C_x	.812
VCG Full Load	15.4 feet
Endurance @ 20 kts	3500 nm.
Sustained Speed	33 knots
Sustained SHP	44,648 SHP
KW Installed	2600 KW
Displacement Full Load	3299 tons
Displacement Light Ship	2409 tons
Variable Loads	890 tons
WTGP 1	1010 tons
WTGP 2	498 tons
WTGP 3	89 tons
WTGP 4	175 tons
WTGP 5	295 tons
WTGP 6	200 tons
WTGP 7	142 tons
Total Internal Volume	353,612 cu.ft.
Superstructure Volume	59,270 cu.ft.
Hull Volume	294,342 cu.ft.
Military Mission Volume	77,251 cu.ft.
Personnel Volume	78,610 cu.ft.
Ship Ops Volume	194,671 cu.ft.
Accommodations	245
Payload Volume Fraction	0.22
Personnel Volume Fraction	0.22
Ship Ops Volume Fraction	0.56
Payload Weight Fraction	0.13
Personnel Weight Fraction	0.05
Ship Ops Weight Fraction	0.47
Ship Density Full Load	20.90 lbs/cu.ft.

TABLE 10

ESTIMATED SOVIET KARA CLASS CHARACTERISTICS

Characteristic	Value
Sustained Max Speed	34 Knots
Endurance Speed	20 Knots
Endurance Range	8750 n.m.
Max Sustained SHP	95,115 SHP
LBP	538 ft.
Beam	51.8 ft.
Draft	20.8 ft.
Depth @ Station 0	54.9 ft.
Depth @ Station 10	38.8 ft.
Depth @ Station 20	39.3 ft.
VCG Full Load	19.4 ft.
Displacement Full Load	8498 tons
Displacement Light Ship	5539 tons
Variable Loads	2959 tons
WTGP 1	2758 tons
WTGP 2	741 tons
WTGP 3	319 tons
WTGP 4	259 tons
WTGP 5	585 tons
WTGP 6	444 tons
WTGP 7	433 tons
Total Internal Volume	867,135 cu.ft.
Superstructure Volume	144,461 cu.ft.
Hull Volume	722,674 cu.ft.
Ship Density Full Load	21.95 lbs/cu.ft.
Payload Volume Fraction	0.17
Personnel Volume Fraction	0.24
Ship Ops Volume Fraction	0.59
Military Mission Volume	150,194 cu.ft.
Personnel Volume	205,558 cu.ft.
Ship Ops Volume	511,383 cu.ft.
Accommodations	540
Payload Weight Fraction	0.09
Personnel Weight Fraction	0.05
Ship Ops Weight Fraction	0.48

b. high speed diesel electric plant specified;

c. aluminum hull material selected;

d. centerline passageway type selected;

e. weight group 201 reduced by 50 tons to allow for eliminating gas turbine enclosure and other items not required on high performance vehicles;

f. weight group 203 reduced by 50% to account for planetary gears and light weight bearings and shafting;

g. machinery box volume reduced by 10%; and,

h. deck height for payload items and raised deck reduced to 8.0 feet.

The resulting characteristics for the high performance designed FFG-7 are listed in Table 11. The model estimates the new design as only 2634 tons with an increase in speed to 33 knots. This is with no reduction in personnel volume, but a reduction in total ship volume of approximately 20%. The resulting model prediction should be a technically feasible ship design, since the inputs to the model represent features which are currently within the state-of-the-art in shipbuilding. Many high performance indices, which would reduce the size of the ship even further, were not considered due to the uncertainties in incorporating these into a conventional displacement hull design.

4.5 Assessment of Results

The model results are considered to be good for conceptual phase estimating of ships in the size range of the data sample. The data sample ships ranged in size from the 301 ft./1770 ton FF-1033 to the 700ft./16,294 ton CGN 9.

TABLE 11

CHARACTERISTICS OF FFG 7 DESIGNED TO

HIGH PERFORMANCE SHIP STANDARDS

CHARACTERISTIC	HIGH PERFORMANCE FFG-7	MODEL FFG-7
Max. Sustained Speed, knots	33.0	30.5
Sustained Speed SHP	40,000	40,000
LBP, ft.	382	408
Beam, ft.	40.2	42.4
Draft, ft.	13.4	16.0
C_p	.593	.593
C_x	.747	.747
VCG Full Load, ft.	17.8	18.4
GM/B	0.08	0.08
Average Depth, ft.	31.0	35.2
Accommodations	185	185
KW Installed	4000	4000
Full Load Displacement, tons	2634	3548
Light Ship Displacement, tons	1666	2460
Variable Loads Weight, tons	886	965
WTGP 1, tons	595	1186
WTGP 2, tons	191	271
WTGP 3, tons	113	167
WTGP 4, tons	123	131
WTGP 5, tons	295	345
WTGP 6, tons	249	260
WTGP 7, tons	100	100
Total Internal Volume, cu.ft.	392,500	493,040
Hull Volume, cu.ft.	301,660	382,335
Superstructure Volume, cu.ft.	90,840	110,705
Full Load Ship Density, lbs/cu.ft.	15.04	16.12
Military Mission Volume, cu.ft.	83,901	89,288
Personnel Volume, cu.ft.	111,050	111,150
Ship Ops Volume, cu.ft.	197,550	292,602
Payload Volume Fraction	0.22	0.18
Personnel Volume Fraction	0.28	0.23
Ship Ops Volume Fraction	0.50	0.59
Payload Weight Fraction	0.13	0.10
Personnel Weight Fraction	0.05	0.04
Ship Ops Weight Fraction	0.47	0.43

The model was built to reflect what were generally the standard features of U. S. ships over the past 25 years. Since the model estimates standard features, the ships predicted by the model at the early conceptual phase level, when only the minimal problem specifications are known, will in most cases be smaller than the actual ships which result. This is because most ships will have some special features which either exceed the standard or for which no standard calculation is provided, e.g., clean ballast system. Some of the features which are generally responsible for size increase are special tankage, increased habitability, and special maintenance and access requirements. This can be seen in Table 3 where ships with few special features, i.e., FFG-2, FF-1040 and CG-26, are predicted very close, but ships like FFG-7 and DD-963 with increased access and habitability requirements are predicted too small. The general trend is that the newer ship designs will have more features which are more demanding than the standard calculations provide, and hence, the newer ships will tend to be underestimated the most.

The results are noted to become more accurate as the input becomes more specific. This was shown in Table 4 where the results became very good with specification of the major ship characteristics which are usually defined early in the design. It is at this point, when the desired standards for habitability, tankage, maintenance, access, etc., have been established, that the model predictions can be made with anticipation of only a small difference from final ship results.

The property of the model which allows increased accuracy

beyond the conceptual formulation is the input array for weights, volumes, vertical centers, etc. It is this feature to update design predictions which would allow for exactly specifying the actual ship if all weights and volumes were input.

When used as a tool for comparative naval architecture, the model gives results which appear to be quite reasonable. The value of the model used in this manner is that it can be used to compare ships for which the design data available ranges from only top level ship characteristics to detailed ship specifications, i.e., Soviet to U. S. ships. When doing comparative studies, whatever information is available for a ship can be directly input to the program. For the case of U. S. ships, the individual weight, volume, vcg, and other special input groups can be directly set into the program to the finest level of detail used in the program and available in the data. The results for this type of ship prediction should be very accurate. For ships where little data is available, the problem specifications, payload items, and any desired special features can be input based upon engineering judgment, any data available, or a best guess. In any case the results should be examined for reasonableness of the prediction.

The model can be used to synthesize ships to certain "design indices". Here design indices refer to a ratio of design impact to capacity, where design impact can be measured as the weight, space, or energy required to provide the specified capacity. To accomplish this for all features an iterative number of runs may be necessary to meet all of the desired indices. After each run the results must be analyzed to determine which inputs should be changed to meet the

desired indices. For example, the machinery box volume per shaft horsepower indice can be met once the installed SHP has been determined by multiplying the two numbers and inputing the result in the input array element for machinery box volume.

The standard relationships used for calculating weights in the program have been found to be very good over the entire range of ships in the data base. This applies to the ships whether large or small in size or old or new in age. Model results have shown that a ship which has the internal volume predicted by the model would have actual weights very close to those estimated by the model standard calculations.

Analysis of model results indicates that the weight required for specific functional items has not changed significantly over the past 25 years; however, the volume required for the same functions has been the driving factor in determining the resulting ship size. In general, it can be said that the full load displacement of a ship carrying a specific payload can vary over a considerable range depending on the volume allocated to the various functional groups. To support this statement, it was found in developing Table 4 that varying the volume for habitability items, tankage, maintenance, and passageways and access, while accepting the standard weight calculations, produced very good results. This seems to indicate that volume requirements in these areas have been those which have deviated from standard practice the most and are the areas where most of the special features of a design are found.

If it were desired to have the model predict ships using the standards of a certain class of ships, e.g., FFG-7, the model

estimating relations which are based on several ship classes could be changed. This could be accomplished with relatively little difficulty since no change to the program logic would be required. This change would probably increase the value of the input array since modeling ships of a class different from the one the model is based upon may require a more detailed input.

The detailed output of the model could provide a basis for budgeting weights and volumes for beginning the preliminary design phase. Once a concept design has been selected, the preliminary phase is generally handled by a number of design teams working in parallel in areas such as combat systems, mobility, ship support, hull structures, habitability, and ship systems. Each of these groups could be assigned the volume and weight groups associated with their areas of functional responsibility as an initial budget or design guide.

This method of providing an initial budget based on model predictions could result in a more efficient ship design than having each design group start with only gross ship characteristics and providing their own first assessment of what they feel they need. If the design groups find that the budgeted weight and volume are just not satisfactory to provide the required functional capabilities at the desired design standards, the acceptable values can be directly input into the corresponding weight and volume groups of the program to override the calculated values. The model can now be used to provide an updated prediction for the ship reflecting the fixed values input. This would also provide the designer with an indication of how changes in one functional group

may have an affect on another group, e.g., adding weight to any weight group will mean added weight and volume for fuel to attain the same endurance. In any event the designer would have an aid in assessing the impact of design changes at any phase of the design.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The synthesis model was found to give results accurate to within about 20 percent when used to predict actual ships using standard input specifications at the level of early conceptual studies. When using this level of input to predict existing ships, the differences between model predictions and actual ship characteristics can generally be explained by special features of the actual ship. Since the model predicts a "standard" value based on the sample data, results at this first and roughest level of modeling will tend to be predicted on the low side. This is true because the model will make its standard estimations considering a ship with essentially no special features.

The computer synthesis model can be used more effectively during the conceptual phase of the design than at any other stage. The model developed in this thesis allows the user to make the same kinds of ship systems level tradeoffs as previous models. Input options are selected for payload and performance features and a series of standard calculations are used to predict the results. The model provides additional versatility at this phase of design, since it enables the designer to directly input values at a more detailed functional level when it is desired to provide features which differ from the standard calculations provided. Results attained when using the model in this manner were shown to be within 5 percent of existing ship values for minimal amounts of additional specification and could be reduced even more if additional items were specified.

The model was also shown to provide a means of conducting comparative studies between ship designs. This is one area where models which can accommodate only one set of design standards cannot be applied. The model used in this manner could be of considerable value when analyzing foreign ship designs where the design standards differ for U. S. practice in most areas. The model can provide a prediction for any existing ship by using specified input values when available and providing the standard calculation if a better value is not available.

Although the synthesis model appears to give accurate results in its current form, there are several areas which are recommended for additional investigation or improvement. The areas which are recommended for future investigation are discussed in the following paragraphs.

With the current limits placed on the C_r array, many ships cannot be run which may be very desirable. Perhaps the best solution to expanding the C_r values available would be the addition of the data from another model test series, such as series 64.

Also, the effect on speed-horsepower predictions caused by sonar domes of modern warships should be included in the horsepower calculating routine. It is felt that the large sonar domes, e.g., SQS 26 bow mounted sonar, could have a noticable effect on speed-power predictions at both endurance and maximum speeds. The current model does not consider the effects of sonar domes.

It is recommended that the payload shopping list data be modified to include the cruise, battle, and 24 hour electric load requirements for each item. This would be especially desirable

for the items which fall under weight groups 4 and 7 (electronics and armament), since these are the most variable items from one ship to the next and the hardest to predict electric loads for.

Since payload items used on naval combatants are continually changing, the payload shopping list should be reviewed periodically to insure that it is kept up-to-date. Some items on the list will require changes as systems are revised. Other items may lose their value on the list and should be deleted, while new items should be added to the list as they become available.

It would also be desirable to include a routine which would consider the topside deck areas required by payload items and the superstructure. In recent years the Naval Ship Engineering Center has developed a significant capability to relate electronic system performance to topside geometry. Information of this type could be used to help set limits on length and height requirements for the superstructure.

An additional recommendation for future development is the addition of a cost routine to the program. Results attained by the program could be used to predict acquisition cost for a lead ship of the design and costs for follow-on ships. Also, relationships could be derived to predict a life-cycle cost which may be of more interest than the acquisition cost.

The model could be modified to handle changes in hull shape which are considerably different from conventional design practice. The model relationships are based on ships of conventional hull shape. New relationships would be required for most all items due to the effects of an unconventional hull shape on features such as

powering, arrangements, structures, access, etc.

As discussed in Section 4.5, the model can be used to design to indices rather than to gross weight and space values. However, the model requires an iteration of synthesis runs which could be expensive and time consuming. It would be desirable to have a model where design indices could be input with the model iterating a balanced solution satisfying the indices.

The ship synthesis model developed in this thesis is intended to serve only as a design tool, and as such, complete reliance should never be placed in the results attained. However, it is felt that if the results are properly analyzed, the model will enhance the design-engineer's ship-design capability. Since the model is only a design tool, the relationships used in the model must be kept current. The users should conduct a periodic review of empirical relations used to insure that they are in agreement with current design policy.

Finally, as has been recommended for several other synthesis models, it is recommended that the model not be programmed as part of a ship optimization routine. Any optimization criteria selected would in general be difficult to define and may result in more desirable ship characteristics being discarded due to biases built into the criteria. It is felt that an experienced designer could better direct the selection of input combinations to be used based on analysis of the previous results attained.

REFERENCES

1. Abbott, Jack W. and Baham, Gary J. "COGAS--A New Look for Naval Propulsion" Naval Engineers Journal, Vol. 86, No. 5, October, 1974, pp. 41-55.

2. Comstock, John P., ed. Principles of Naval Architecture. New York: The Society of Naval Architects and Marine Engineers, 1967.

3. ✓"Conceptual Design of Ships Model (CODESHIP) (U)." Center for Naval Analyses, Research Contribution 159, Volumes I through IV, December, 1971.

4. "Consolidated Weight Listing for Various U. S. Navy Cruiser/ Destroyers," Naval Ship Engineering Center, 1975.

5. Cotton, James L. "Fourth Update of CODESHIP Payload Shopping List." Center for Naval Analyses, CNA 662-75, 2 May 1975.

6. "Electric Power Analysis for DLG-9, DDG-2, DEG-1, DE-1052, DDG-FY67, DD-963, FFG-7."

7. Gertler, Morton, A Reanalysis of the Original Test Data for the Taylor Standard Series, David W. Taylor Model Basin Report 806, Washington, D.C.: U. S. Government Printing Office, 1954.

8. ✓ Goodwin, Michael J. Ship Synthesis Model for Coast Guard Cutters. Massachusetts Institute of Technology, Department of Ocean Engineering, Thesis, June, 1975.

9. Graham, C. and Hamly, R. "Simplified Math Model for the Design of Naval Frigates." Massachusetts Institute of Technology, Department of Ocean Engineering, Course 13.411 Handout, Lectures 5 through 8, September, 1975.

10. Johnson, Robert S. "Ship Synthesis Models--With Examples." Naval Ship Engineering Center, Hyattsville, Md.

11. Kehoe, Capt. James W., Jr. "Warship Design--Ours and Theirs." Naval Engineers Journal, Vol. 88, No. 1, February, 1976, pp. 92-100.

12. Libby, D. A. "A Guide for Estimating the Propulsion Plant Weight for Naval Type Surface Ships." Naval Ship Engineering Center Code 6144, February 1970.

13. Mason, T. W. "Data Subroutine CNA Computer Program 13-655." Center for Naval Analyses Research Contribution No. 14, 26 August 1965.

14. Menz, M. G. "Ship Design Analysis--Machinery Box Estimating Procedures." Naval Ship Engineering Center Memo 6152: MGM:dcd, Ser 131, 29 April 1969.

15. Mills, J. "Feasibility Studies and Ship Synthesis Models." Lectures 7, 8 and 9. Unpublished lecture notes for Professional Summer at M.I.T.

16. Naval Vessel Register/Ships Data Book, Naval Sea Systems Command, Washington D.C., 1 July 1975.

17. "Proposed U.S. Navy Space Classification Manual." Naval Ship Engineering Center, December, 1969.

18. Shen, Michael and Gale, Peter. "A Procedure for Predicting the Speed of Surface Ships in Rough Head Seas." Naval Ship Engineering Center Report No. 6114-71-4, 1970.

19. Shen, Michael, Gale, Peter A., and Walker, Kenneth. "An Improved Procedure for Predicting the Speed of Surface Ships in Rough Head Seas." Naval Ship Engineering Center Report No. 6114-71-8, 1970.

20. "Ship Work Breakdown Structure." NAVSHIPS 0900-039-9010, Naval Ship Systems Command, Department of the Navy, Washington, D.C. 20360, 1 March 1973.

21. Smith, L. C. "Ship Space Classification Data." Ship Concept Design Division, Naval Ship Engineering Center, March, 1970.

22. "Summary of Compartment Volumes and Deck Areas for DD-963." Contract No. N00024-70-C-0275, ID No. DD75-010, Ingalls Shipbuilding, Pascagoula, Mississippi, 12 November 1975.

23. Ward, W. K. "A Method for Estimating the BSCI Group 203 Weight During Concept Formulation and Feasibility Studies." Naval Ship Engineering Center Code 6144, May 1968.

APPENDIX A

USERS GUIDE

APPENDIX A

USERS GUIDE

General

This Appendix is intended to serve as a guide for preparing data and specifications for the computer synthesis model listed in Appendix E. For proper use of the computer model it is mandatory that the data input follow the outline of this Appendix.

Input for the model can be divided into two main groups. The first group containing the data for the list of symbols (names) to be used in the output, the C_r arrays used in estimating propulsion power, and the payload data describing the payload characteristics. The second group contains the data for individual ship runs.

The computer cards for each job run should be set up in the following order:

Control Cards

Main Program

All Subroutines

Control Card for Data Input

Symbol Cards

C_r Data Cards

Payload Data Cards

Blank Card

Ship No. 1 Specifications

Blank Card

Ship No. 2 Specifications

Blank Card

Ship No. 3 Specifications

Blank Card

Etc.

Ship No. n Specifications

Blank Card

Blank Card

Control Card

The symbol cards and C_r cards are read by the main program and must be in the proper order with no blank cards between them, although some blank cards are included in the symbol data. The payload data is read by subroutine DATA2 and requires the blank card after the last payload item to return control to the main program. The symbol cards, C_r array cards, and payload item cards are read into the program only once and are stored in arrays for use with all test cases run.

The data cards containing the specifications for each ship are also read in by subroutine DATA2 and must be followed by a blank card to return control to the main program to allow calculation for each ship to proceed. Two blank cards are required at the end of the data deck. The first blank card serves the same purpose as the preceeding blank cards, i.e., returns control to the main program to calculate ship results. The second blank card indicates that no additional ships are to be calculated and directs program execution to stop.

Data for the symbols, C_r arrays, and payload items is listed following the program listing in Appendix E.

Ship Specification

In order to set the input specifications for each ship to be run, a specification array of 2500 elements is used. It is through use of this input array that the versatility of the program is utilized.

The specifications are numbered for use by the computer. The blocks of the array are divided as listed below:

Blocks	Use
1-99	To define performance, hull, power plant, accommodations, special features, and calculation control.
100-299	For specifying the payload items and quantity.
300-1099	To directly input the weight of any of the BSCI weight groups. This overrides any program calculation.
1100-1899	To directly input the vertical center of gravity of any of the BSCI weight groups. This overrides any program calculation.
1900-2199	To directly input the volume of any of the functional groups of Appendix C. This overrides any program calculation.
2200-2249	To directly input the electric load (cruise, battle, or 24 hour average) for any electric load group. This overrides any program calculation.

2250-2299	For specifying certain miscellaneous program parameters or coefficients.
2300-2500	For inputing any special payload items desired which are not included in the payload shopping list.

The primary specifications for any ship run are those defined as the problem specifications in Table 12. This table lists several options which are available to the user in specifying each ship.

The user should keep in mind while preparing input data for each ship that the program initially sets all elements of the specification array to zero. Therefore, care must be taken to insure a value is input for every appropriate non-zero specification. Also, for each succeeding ship after the first one, the values of the specifications remain the same unless the appropriate element is changed.

The user has the option of selecting either the sustained speed (number 1) or the SHP at sustained speed (number 12). If both are specified, the SHP is used and VSUS is ignored.

The length between perpendiculars, LBP, (number 4) may be selected or values for L/B and B/H must be input. If L/B and B/H are specified, but not LBP, the program will calculate a value for LBP and proceed. However, if LBP is specified the input values for L/B and B/H are ignored and the input LBP is used.

The number of boilers must be specified if conventional steam propulsion is selected. Also, the number of boilers and reactors must both be specified if nuclear propulsion is desired. In all

cases the number of main propulsion engines and number of shafts must be specified.

Values for propeller rpm and diameter may be specified, if desired. If not specified, a calculation is made for each of these variables to allow estimating BSCI weight group 203.

The machinery box dimensions may be input, but it is required that if any one of the dimensions (numbers 21,22 and 23) is input that all three be specified. The machinery box volume may also be input using element number 2121 as explained in the following paragraphs or a calculation will be made by the program.

Propulsive coefficients used in estimating shaft horsepower at sustained and endurance speeds may be input. If not input, values of 0.67 and 0.65 are used, respectively.

The frictional resistance correction factor (number 26) may be specified. This value is used in the horsepower calculation. A value of 0.0004 is used if none is input.

The ship service electric and emergency electric plant types must be specified. Item numbers 33 through 40 may be left as zero if it is desired to have the program size the electric plant. However, if any of items 33 through 40 are specified, then the entire electric plant must be specified, e.g., 4 steam turbine generators at 500 KW each and 2 low speed diesel generators at 300 KW each.

The free surface correction (number 71) may be entered to adjust the KG above or below the average built into the program and may be entered as a positive or negative number.

For other specifications a value should be selected as suggested by Table 12.

Payload specification is accomplished by use of specifications 100 through 299 as shown in Table 13. Up to 100 items may be specified, in any quantity for each item. The quantity is to be given as an even numbered specification, starting at 100. The associated item number is to be given as the next specification in each case.

The program has been developed to allow the user to specifically input any weight group, volume group, center of gravity, or electric load group that may be desired. This capability may be especially useful in later stages of a design as more and more characteristics of the ship become fixed. For example, if the propulsion plant had been selected, the user could directly input most of the BSCI Group II weights. The input weights would override any calculated values and improve the accuracy of the overall ship characteristic estimates. The user should then be able to continually update the prediction of the final ship, until in the end, the entire ship is specified. The specification numbers which correspond to the weights, vcg's, volumes, and electric loads are found in Tables 14, 15, 16, and 17, respectively.

During execution of the program the values of elements 300 through 2249 of Tables 14, 15, 16, and 17 are checked for a non-zero value. Non-zero values found are used; however, if the element is left zero the standard calculation is made to estimate the appropriate item. Because of this feature, if it is desired that a function have the value of zero, a small positive value must instead be input, e.g., to make volume group 311 equal zero, input item 2111 equal to 0.01. The exception to the above is that

volumes for functional groups 100, 110, 120, 130, 200, 210, 220, 230, 300, 310, 320, 330, 340, 350 and 360 may not be specified directly since they are calculated by summing other volumes.

A list of miscellaneous specifications is provided in Table 18. Not all of the elements in this list have been used, and therefore, the capability exists to readily add more items. Elements 2250 through 2273 have been used to reflect desired changes in primarily personnel related area. As shown in Table 18 these elements are used as multipliers or coefficients to change the calculated value of certain volume groups. Table 20 is provided to suggest a range of values which might be used for these elements. The DD 931 and FFG 7 were selected to generally reflect the two extremes in personnel related volumes required (mainly habitability areas) in current U. S. Navy ships. When not input, a multiplier of 1.0 is assigned.

Item 2274 allows for input of the deck height to be used in calculating volumes for payload items and also in computing volumes associated with an added raised deck. If no value is input a value of 9 feet is assumed. Item 2299 is used to input the machinery box prismatic coefficient. When not input, a value of 0.95 is assumed.

Table 19 indicates how special payload items not identified in the payload shopping list at the end of this Appendix may be input. The information required for special items is the same as that of regular payload items. The appropriate weight and volume groups must be entered along with weight, vcg, and area requirements.

Payload Shopping List

A key element in preparing the input for a ship run is the specification of the ship payload items. The list of payload items available for selection is given in Table 21. This list was developped by selecting appropriate items from those available in Reference (5).

While the definition of each payload item is given in Table 21, the characteristic data for each item is found in the payload data listing included in the program listing of Appendix E. Each line of payload data contains the payload item number followed by seven numbers separated by blanks. The data should be interpreted as shown by the following example using payload item 15:

A	B	C	D	E	F	G	H
1,15	408	112	9.8	12.0	1	210	100

where A = item number (15)

B = weight group number (408)

C = functional volume group number (112)

D = item installed weight in tons (9.8)

E = center of gravity location (feet/factor)*(12.0)

F = center of gravity reference index* (1)

G = deck area inside the superstructure (sq.ft.)(210)

H = deck area in the hull (sq.ft.)(100)

* 1 = item location relative to strength deck (feet)

2 = item location relative to keel (feet)

3 = item location as fraction of ship hull depth at station 10.

Example Ship Input

As an example, input data for a ship might look like the following:

```
column 1               column 20
1 0 20 4500 408 0 0 .59 .75 0 0 6 40000 0 0 2 1
17 2 1 0 0 0 0 0 .66 .67 .0005 0 0 0 0 5 4 0 4
35 0 0 0 1000 0 0 .30 0 0 0 2 2 0 0 0 14 15
52 156 0 0 0 45 0 0 0 0 1 2 0 .75 0 10 20
68 .10 20 .05 0 2 0 0 2
100 1 2 1 24 1 27 1 41 1 61 8 64 1 65 1 75
116 1 100 1 102 1 116
312 40.5
1825 17.2
2161 9000 0 13000
2250 1.32
```

Since the ship specifications are read in under subroutine DATA2, Chapter 3 provides the information on how to code the input data. A sample input is given in the listing at the end of Appendix E. In the example above a few selected specifications are:

Item 1	= 0	VSUS not specified
Item 4	= 408	LBP specified
Item 12	= 40000	SHP specified
Item 17	= 2	controllable pitch propeller specified
Item 62	= 2	aluminum superstructure specified
Item 100	= 1	quantity of 1 of item 101 specified
Item 101	= 2	payload item number 2 specified
Item 2161	= 9000	volume of ballast tankage specified

Item 2162 = 0	volume of peak tankage not specified so will be calculated, but a 0 was entered to allow item 2163 to be specified as 13000

TABLE 12

PROBLEM SPECIFICATIONS

Number	Definition
1	Sustained speed, knots
2	Endurance speed, knots
3	Endurance range, nautical miles
4	Length between perpendiculars, feet
5	Length-beam ratio (L/B)
6	Beam-draft ratio (B/H)
7	Prismatic coefficient (Cp)
8	Midship section coefficient (Cx)
9-10	Not used
11	Propulsion plant type: 1. 600 psi steam 2. 1200 psi steam 3. 1200 psi pressure fired steam 4. nuclear 5. gas turbine 1st generation 6. gas turbine 2nd generation 7. diesel 8. COGAS
12	Sustained speed shaft horsepower, SHP
13	Number of boilers
14	Number of nuclear reactors
15	Number of main propulsion engines
16	Number of shafts
17	Propeller type: 1. fixed pitch 2. controllable pitch
18	Shaft type: 1. Hollow 2. Solid
19	Shaft RPM (optional)
20	Propeller diameter, feet (optional)
21	Depth of machinery box, feet (optional)
22	Length of machinery box, feet (optional)
23	Beam of machinery box, feet (optional)
24	Propulsive coefficient at endurance speed (optional)
25	Propulsive coefficient at maximum sustained speed (optional)
26	Frictional resistance correction factor, ΔC_F (optional)
27-30	Not used
31	Ship service electric plant type: 1. steam 2. gas turbine 1st gen. 3. gas turbine 2nd gen. 4. low speed diesel 5. medium speed diesel 6. high speed diesel
32	Emergency electric plant type: 1. gas turbine 1st gen. 2. gas turbine 2nd gen. 3. low speed diesel 4. medium speed diesel 5. high speed diesel

TABLE 12 (continued)

Number	Definition
33	Number of low speed diesel generators (optional)
34	Number of medium speed diesel generators (optional)
35	Number of high speed diesel generators (optional)
36	Number of gas turbine generators (optional)
37	Number of steam turbine generators (optional)
38	KW per diesel generator (optional)
39	KW per gas turbine generator (optional)
40	KW per steam generator (optional)
41	Electric plant design margin (e.g., .30)
42-44	Not used
45	Type of ship heating: 1. steam 2. electric
46	Fin stabilizers desired: 1. no 2. yes
47-49	Not used
50	Ship officer personnel accommodations
51	Ship CPO personnel accommodations
52	Ship enlisted personnel accommodations
53	Flag personnel accommodations
54	Troop accommodations
55	Passenger accommodations
56	Ship accommodations duration, days
57-60	Not used
61	Basic hull material: 1. steel 2. aluminum
62	Basic superstructure material: 1. steel 2. aluminum
63	Not used
64	GM/B stability value (e.g., .10)
65	Not used
66	Tolerance for displacement iterations, tons (e.g., 2)
67	Maximum number of displacement iterations
68	Tolerance for vertical center of gravity iteration, feet (e.g., .1)
69	Maximum number of center of gravity iterations
70	Design, construction margin (e.g., 10% margin entered as 0.10)
71	Free surface correction, feet
72	Print index, number of pages: 0. input plus summary of results 1. above plus functional listing 2. all of above plus BSCI weight groups and electric loads
73	Miscellaneous coefficients print index: 0. don't print constants 1. print constants
74	Not used

TABLE 12 (continued)

Number	Definition		
75	Passageway type:	1.	centerline
		2.	port & starboard
76-99	Not used		

TABLE 13

PAYLOAD SPECIFICATIONS

Number	Definition
100	Quantity of payload item in 101
101	Payload item number (payload shopping list)
102	Quantity of payload item in 103
103	Payload item number (payload shopping list)
104	Quantity of payload item in 105
105	Payload item number (payload shopping list)
...	
298	Quantity of payload item in 299
299	Payload item number (payload shopping list)

TABLE 14

WEIGHT SPECIFICATIONS

Number	Definition
300	Input of BSCI* Weight Group 100, tons
301	Input of BSCI* Weight Group 101, tons
302	Input of BSCI* Weight Group 102, tons
...	
400	Input of BSCI* Weight Group 200, tons
401	Input of BSCI* Weight Group 201, tons
...	
900	Input of BSCI* Weight Group 700, tons
...	
903	Input of BSCI* Weight Group 703, tons
904	Input of BSCI* Weight Group 704, tons
...	
1000	Input of BSCI* Weight Group 800*, tons
....	
1099	Input of BSCI* Weight Group 899*, tons

NUMBER = BSCI WT GRP + 200

*Modification to 1965 BSCI weight listing found in Appendix C.

TABLE 15

VCG SPECIFICATIONS

Number	Definition
1100	Input of VCG for BSCI* Weight Group 100, feet
1101	Input of VCG for BSCI* Weight Group 101, feet
1102	Input of VCG for BSCI* Weight Group 102, feet
....	
1200	Input of VCG for BSCI* Weight Group 200, feet
1201	Input of VCG for BSCI* Weight Group 201, feet
....	
1700	Input of VCG for BSCI* Weight Group 700, feet
....	
1703	Input of VCG for BSCI* Weight Group 703, feet
1704	Input of VCG for BSCI* Weight Group 704, feet
....	
1800	Input of VCG for BSCI* Weight Group 800*, feet
....	
1899	Input of VCG for BSCI* Weight Group 899*, feet

NUMBER = BSCI WT GRP + 1000

*Modification to 1965 BSCI weight listing found in Appendix C.

TABLE 16

VOLUME SPECIFICATIONS

Number	Definition
1900	Functional volume group 100**, cubic feet
....	
1911	Functional volume group 111, cubic feet
....	
2000	Functional volume group 200, cubic feet
....	
2100	Functional volume group 300, cubic feet
....	
2199	Functional volume group 399, cubic feet

NUMBER = FUNCTIONAL VOL GRP + 1800

**Functional Classification System defined in Appendix C.

TABLE 17

ELECTRIC LOAD SPECIFICATIONS

Number	Definition
2200	Electric cruise load group 100, KW
2201	Electric cruise load group 200, KW
....	
2208	Electric cruise load group 900, KW
2209	Electric cruise load margin, KW
2210	Electric cruise load total, KW
2211	Electric battle load group 100, KW
2212	Electric battle load group 200, KW
....	
2219	Electric battle load group 900, KW
2220	Electric battle load margin, KW
2221	Electric battle load total, KW
2222	Electric 24 hour average load group 100, KW
2223	Electric 24 hour average load group 200, KW
....	
2230	Electric 24 hour average load group 900, KW
2231	Electric 24 hour average load margin, KW
2232	Electric 24 hour average load total, KW

TABLE 18

MISCELLANEOUS SPECIFICATIONS

Number	Definition
2250	Multiplier for calculated value of volume group 211
2251	Multiplier for calculated value of volume group 212
2252	Multiplier for calculated value of volume group 213
2253	Multiplier for calculated value of volume group 214
2254	Multiplier for calculated value of volume group 215
2255	Multiplier for calculated value of volume group 216
2256	Multiplier for calculated value of volume group 217
2257	Multiplier for calculated value of volume group 218
2258	Multiplier for calculated value of volume group 219
2259	Multiplier for calculated value of volume group 221
2260	Multiplier for calculated value of volume group 222
2261	Multiplier for calculated value of volume group 223
2262	Multiplier for calculated value of volume group 224
2263	Multiplier for calculated value of volume group 225
2264	Multiplier for calculated value of volume group 231
2265	Multiplier for calculated value of volume group 232
2266	Multiplier for calculated value of volume group 233
2267	Multiplier for calculated value of volume group 311
2268	Multiplier for calculated value of volume group 313
2269	Multiplier for calculated value of volume group 325
2270	Multiplier for calculated value of volume group 341
2271	Multiplier for calculated value of volume group 342
2272	Multiplier for calculated value of volume group 343
2273	Multiplier for calculated value of volume group 370
2274	Input for value to be used for deck height, feet
2275 thru 2298	Not used
2299	Input for value of machinery box prismatic coefficient

TABLE 19

SPECIAL PAYLOAD SPECIFICATIONS

Number	Definition
2300	BSCI weight group of first special payload item
2301	Functional volume group of first special payload item
2302	Weight of first special payload item, tons
2303	Center of gravity location (feet/factor)* first item
2304	Center of gravity reference index* first item
2305	Deck area inside superstructure for first item (sq.ft.)
2306	Deck area inside hull for first item (sq.ft.)
2307	Not used
2308	Not used
2309	Not used
....	
....	
....	
2490	BSCI weight group of twentieth special payload item
2491	Functional volume group of twentieth special payload item
2492	Weight of twentieth special payload item, tons
2493	Center of gravity location (feet/factor)* twentieth item
2494	Center of gravity reference index* twentieth item
2495	Deck area inside superstructure for twentieth item (sq.ft.)
2496	Deck area inside hull for twentieth item (sq.ft.)
2497	Not used
2498	Not used
2499	Not used
2500	Not used

*1 = item location relative to strength deck (feet)
2 = item location relative to keel (feet)
3 = item location as fraction of ship depth at station 10

TABLE 20

EXAMPLE COEFFICIENTS FOR MISCELLANEOUS SPECIFICATIONS
(Personnel Related Items)

Element Number	SHIP DD 931*	SHIP Model Standard	SHIP FFG 7*
2250	.71	1.0	1.32
2251	.77	1.0	1.17
2252	.63	1.0	.77
2253	.68	1.0	1.11
2254	.57	1.0	.94
2255	.57	1.0	.93
2256	.92	1.0	.99
2257	.74	1.0	1.42
2258	.82	1.0	1.18
2259	.55	1.0	1.33
2260	.61	1.0	1.12
2261	.34	1.0	2.23
2262	.34	1.0	1.72
2263	.24	1.0	3.30
2264	1.01	1.0	.96
2265	.24	1.0	1.72
2266	.60	1.0	2.82
2267	.66	1.0	1.03
2268	.77	1.0	2.69
2269	.75	1.0	1.65
2270	.85	1.0	1.33
2271	.98	1.0	1.73
2272	1.19	1.0	.62
2273	1.04	1.0	1.10

*DD 931 and FFG 7 were selected to indicate the recommended range for coefficients, since DD 931 was launched in 1955 and FFG 7 is scheduled for launch in 1977.

TABLE 21

PAYLOAD SHOPPING LIST

ITEM	DEFINITION
Radio Communications	
1	FF(Non ASW Command and Cont)
2	FF(ASW Command and Control)
3	DDG
4	Baseline Strike Cruiser
5	CG/CGN
6	Blank
Radars	
7	Target Acquisition System Mod 0
8	Target Acquisition System Mod 3
9	SPS 10
10	SPS 10 W/IFF
11	SPS 26
12	SPS 29
13	SPS 30
14	SPS 37
15	SPS 39A
16	SPS 40
17	SPS 40 W/IFF
18	SPS 40A W/IFF
19	SPS 43
20	SPS 43 W/IFF
21	SPS 48 (V)
22	SPS 48C
23	SPS 49
24	SPS 49 W/IFF
25	SPS 52B
26	SPS 53
27	SPS 55 W/IFF
28	SPS 48A (MTI)
29	SPS 58
30	SPN 6
31	SPN 10
32	SPN 12
33	SPN 35
34	SPN 42
35	Beacon Video Processor
36	SPH 2 (RAVIR MOD 3)
37	SPS 58C
38	Blank
39	Blank
Sonars	
40	SQS 53
41	SQS 56
42	SQS 23 (TRAM)
43	SQQ 23
44	SQS 26 (CX)
45	EDD 610E
46	SQA 13 (VDS)
47	SQS 35 (IVDS)
48	UQN 4
49	SQS 23
50	TACTLASS
51	Escort Towed Array System (ETAS)
52	SQS 38 (keel)
53	505 Sonar
54	Blank
55	Blank

TABLE 21 (continued)

ITEM	DEFINITION
Sonar Domes	
56	23 Keel Dome (Double, Rubber)
57	23 Bow Dome
58	26.53 Bow Dome
59	610E/505 Bow Dome
60	23 Keel Dome
61	610E/505 Keel Dome
62	23 Keel Dome (Rubber)
63	Blank
Sonar Liquid	
64	Sonar Liquid (1 ton)
Electronic Countermeasures (ECM)	
65	FF/FFG Basic
66	DD/DDG/CG/CGN Basic
67	SLQ 17
68	ALR 59
69	WLR-8
70	SLR-10 or BRD-4, SLR-11
71	DTP Suite Three
72	Blank
Electronic Tactical Data Systems	
73	Conc C and C-FF
74	Conv C and C-DD
75	ASW C and C-FF-2C, 7D
76	NTDS - 4C, 13D - DG/DGN
77	NTDS - 2C, 9D - DDG
78	NTDS - 3C, 15 - 18D
79	NTDS - 3C, 15D - CG
80	NTDS - 3C, 15D - CGN
81	SSCDS - 1C
82	Conv C and C - CG, CGN
83	Blank
Guns and Ammo Handling and Stowage	
84	3/50 SM, MK-34 w/Shield Mn DK
85	3/50 SM, MK-34 w/Shield 01 LV
86	3/50 SM, MK-34 w/o Shield 01 LV
87	3/50 TM, MK-33 w/ Shield Mn DK
88	3/50 TM, MK-33 w/Shield 01 LV
89	3/50 TM, MK-33 w/o Shield Mn DK
90	3/50 TM, MK-33 w/o Shield 01 LV
91	5/38 SM, MK-30 Mn DK
92	5/38 SM, MK-30 01 LV
93	5/54 SM, MK-42 Mn DK
94	5/54 SM, MK-42 01 LV
95	5/54 SM, LW, MK-45/0 Mn DK
96	5/54 SM, LW, MK-45/0 01 LV
97	8/55 SM, MK -71 Mod 0 Mn DK
98	8/55 SM, MK-71 Mod 0 01 LV
99	50 Cal MG 02 LV
100	Vulcan/Phalanx 01 LV
101	35 mm twin 01 LV
102	76 mm single 01 LV
103	76 mm single Mn DK
104	Blank
105	Blank

TABLE 21 (continued)

ITEM	DEFINITION
Gun Fire Control Systems	
106	MK-86 (CSG)
107	MK-37
108	MK-56
109	MK-63/26
110	MK-68/6
111	GFCS for 5"/54 w/AEGIS ILL.
112	MK-86 (LFS) Mod 3
113	MK-86 (LFS) Mod 4
114	MK-86 with AAW and CWI MOD 5
115	MK-87
116	MK-92 CWI/STIR
117	MK-86 - 5 w/o SPQ 9
118	Blank
Gun Ammo	
119	3"/50 Rd.
120	5"/38 Rd.
121	5"/54 Rd.
122	8"/55 Rd.
123	40 mm
124	20 mm
125	Blank
126	Blank
Rocket and Missile Launchers	
127	NATO Sea Sparrow, MK-2910 (8 boxes)
128	Terr-40, MK-10/3-6
129	Terr-60, MK-10/7-8 Mn DK
130	Terr-60, MK-10/7-8 01 LV
131	Tartar, MK-13
132	Tartar, MK-22
133	Tartar, MK-11
134	BPDMS, MK-25
135	GMLS, MK-26 (MOD 0)
136	GMLS, MK-26 (MOD 1)
137	GMLS, MK-26 (MOD 2)
138	5" SSR, MK-105
139	CHAFFROC, 4 Launch
140	Harpoon Launcher (MK-13)
141	Harpoon (Box) w/4 Missiles
142	IPMDS Launcher
143	Redeye
144	Sea Launched Cruise Missile (SLCM) w/4 missiles
145	Near Term Laser Pointer Trainer
146	Tarpon Canister Launcher w/4 missiles
147	Blank
ASW Rocket and Missile Launchers	
148	ASROC-8, MK-16/4 w/8 ASROC, 01 Level
149	ASROC-8, MK-16/4 w/8 ASROC, o2 Level
150	ASROC Reload, Mag & Handling Gear
151	DASH Launch (Hangar)
152	Blank
Missile Fire Control Systems	
153	Near Term Laser System less Pointer Trainer
154	Sea Launched Cruise Missile FCS
155	Weapons Direction System MK-13
156	MK-74 FCS (1 DIR) (Tartar C)
157	MK-74 FCS (2 DIR)

TABLE 21 (continued)

ITEM	DEFINITION
158	MK-115 BPDMS FCS
159	CHAFFROC FCS
160	MK-91 GMFCS (1 Chan)
161	MK-91 GMFCS (2 Chan)
162	MK-7/1 Aegis (2 Slaved)
163	MK-7/1 Aegis (2 Slaved, 1 Track)
164	MK-7/1 Aegis (3 Slaved, 1 Track)
165	Harpoon FCS
166	Blank
Missile & Rocket Ammo	
167	RIM 67A-Ter 3 DK
168	RIM 66A-Tartar 2 DK
169	RIM 67A-Ter 2 DK
170	RIM 66A-Tartar MN DK
171	RIM 7H Sparrow
172	5" Rocket, MK-10
173	CHAFFROC
174	Harpoon
175	Blank
Torpedo Tubes, Handling & Stowage	
176	MK-25 TT 2 DK
177	MK-25 TT 01 LV
178	MK-32 Twin Mn DK
179	MK-32 Twin 01 LV
180	MK-32 Triple
181	Torpedo Countermeasure Launchers
182	Hedgehog
183	Blank
ASW and Torpedo Fire Control Systems	
184	MK-114 UBFCS
185	MK-114/12 UBFCS
186	MK-116 UBFCS
187	Drone Control SRW4C w/URW 15
188	Drone Control SRW4C
189	TORP FCS (MK-25) (Hull)
190	TORP FCS (MK-25) (Supstr)
191	Tarpon FCS Interface Alterations
192	Blank
ASW Ammo	
193	ASROC Reload (02 Level)
194	ASROC Reload (01 Level)
195	MK-37/0,3 2 DK
196	MK-37/0,3 01 LV
197	MK-37/1,2 2 DK
198	MK-44 Mn DK
199	MK-44 01 LV
200	MK-46 MnDK
201	MK-48 Mn DK
202	MK-48 2 DK
203	Blank
Helos	
204	Two LAMPS III (main deck)
205	HASP-T Helo (main deck)
206	Blank
207	Blank

TABLE 21 (continued)

ITEM	DEFINITION
Helo Support	
208	LAMPS MK III Package
209	LAMPS Control
210	LAAV 1
211	LAAV 2
212	LAMPS (Platform & Refuel)
213	One LAMPS III Hangar
214	Helo Tie-Down
215	Aero Stores (1000 ft^3)
216	Blank
Aviation Liquids	
217	JP 5 (100 gal.)
218	Av Gas (100 gal.)
219	Av Lube Oil (100 gal.)
220	Blank
Small Arms	
221	Misc. - FF/FFG
222	Misc. - DD/DDG/CG
223	Misc. - Cruiser
224	Misc. - (Marine Detach.)
225	Misc. - Small Ships
Aviation Ammo	
226	MK-46 Torp
227	Blank
228	Blank
229	Blank

ITEM	DEFINITION
Sewage Treatment Plant	
230	Sewage Treatment Plant (175 man)
231	Blank
Replenishment at Sea & Cargo Handling	
232	FAST System - Dest/Cruiser
233	Blank
Liquids	
234	NSFO (100 gal.)
235	Diesel Oil (100 gal.)
236	Potable Water (100 gal.)
237	Liquid O_2 (100 gallons)
238	Auto Gas (100 gal.)
239	Blank
Boats	
240	14' Punt
241	26' Motor Whale Board (Wherry)
242	26' Personnel
243	28' Personnel
244	33' Utility
245	33' Personnel
246	35' Motor Boat
247	40' Utility
248	40' Personnel
249	50' Motor Launch
250	50' Utility
251	Blank

TABLE 21 (continued)

ITEM	DEFINITION
Future Development	
252	Weight Margin (1 ton)
Undefined Items	
253 thru 300	Blank

APPENDIX B

SAMPLE OUTPUT

APPENDIX B

SAMPLE OUTPUT

A sample output is provided in this appendix. The output printed consists of the ship specifications, special payload input, payload specifications, summary of results, functional grouping results, BSCI weight listing, and functional electric loads.

The first items printed in the output are the ship specifications. The 75 ship specifications are printed in three columns of 25 each. Column 1 gives the specifications of items 1 through 25 of Table 12. Items 26 through 50 of Table 12 are presented in column 2 and items 51 through 75 are found in column 3.

The special payload input is printed in the format specified in Appendix A.

The payload specifications are printed next. The item number of each payload item selected from the shopping list is printed with the quantity of the item.

The summary of results gives the overall ship characteristics for the ship run plus a listing of some selected ratios. The nomenclature used for most of the items in the summary of results are found in Appendix F. For those items not found in Appendix F, the following definitions are provided:

LEN R DK	Length of raised deck added, ft.
VCG FLD	Full load ship center of gravity, ft.
SUS SHP	SHP at maximum sustained speed
END SHP	SHP at endurance speed
AVSEASPD	Average sea speed in North Atlantic Ocean, knots
NU ACCOM	Total number of accommodations on ship

FLD DENS	Ship density at full load, lbs./cu.ft.
LSP DENS	Ship density at light ship, lbs./cu.ft.
WPAY/FLD	Payload weight fraction
WPER/FLD	Personnel weight fraction
WOPS/FLD	Ship operations weight fraction
VPAY/VOL	Payload volume fraction
VPER/VOL	Personnel volume fraction
VOPS/VOL	Ship operations volume fraction
WTG2/SHP	Ratio of weight group 2 to SHP, lbs./SHP
VMB/SHP	Ratio of machinery box volume to SHP, cu.ft./SHP
WT3/KWIN	Ratio of weight group 3 to installed KW, tons/KW
WTG1/VOL	Ratio of weight group 1 to total volume, lbs./cu.ft.
WTG5/VOL	Ratio of weight group 5 to total volume, lbs./cu.ft.
VHAB/MAN	Ratio of volume of personnel living and support to total accommodations, cu.ft./man
WHAB/MAN	Ratio of weight of personnel living and support to total accommodations, lbs./man
MEN/DISP	Ratio total accommodations to full load displacement, men/ton
KWIN/FLD	Ratio of installed KW to full load displacement, KW/ton
SHP/DISP	Ratio of SHP to full load displacement, SHP/ton
DP*V/SHP	Ratio of full load displacement times VSUS to SHP (transport efficiency), dimensionless
WPY*V/DP	Ratio of payload weight times VSUS to full load displacement, knots

The ship constants as defined in Table 18 are presented next. These are followed by the detailed results for the functional groupings of Appendix C, Table 22.

Results for the BSCI weight listing as given in Table 23 of Appendix C follow the functional grouping results. The last results printed are the functional electric loads as described in Section 3.9.

SHIP NUMBER 2

SHIP SPECIFICATIONS

VSUS	0.00	DELTA CP	5.00	CPO ACC	15.00
VEND	20.00		0.00	CREW ACC	156.00
RANGE	4500.00		0.00	FLAG ACC	0.00
LBP	408.00		0.00	TRP ACC	0.00
L/B	9.07		0.00	PASS ACC	0.00
B/H	3.14	SSEL TYP	5.00	DAYS DUR	45.00
CP	0.59	EMEL TYP	4.00		0.00
CX	0.75	NU LOWSD	0.00		0.00
	0.00	NU MEDSD	4.00		0.00
	0.00	NU HI SD	0.00		0.00
PROP PLT	6.00	NU GT GN	0.00	HULL MAT	1.00
SUS SHP	40000.00	NU ST GN	0.00	SUPSTMAT	2.00
NU BOILS	0.00	KW/DIESL	1000.00		0.00
NU REACT	0.00	KW/GAS T	0.00	GM/B MIN	0.08
NU ENGS	2.00	KW/STM G	0.00		0.00
NU SHAFT	1.00	ELC MARG	0.30	DISP TOL	10.00
PROPELLR	2.00		0.00	MXDIS IT	20.00
SHFT TYP	1.00		0.00	VCG TOL	0.10
PROP RPM	0.00		0.00	MXVCG IT	20.00
PROP DIA	0.00	HEAT TYP	2.00	DCWTMARG	0.05
DEPTH MB	0.00	FIN STAB	2.00	FS CORR	0.00
LENTH MB	0.00		0.00	PRNT TYP	2.00
BEAM MB	0.00		0.00	PRNTCNST	1.00
PC END	0.00		0.00		0.00
PC MAXSP	0.00	OFF ACC	14.00	PASSAGE	2.00

PROP PLT	GASTURB2	SHFT TYP	HOLLOW	HULL MAT	STEEL
SSEL TYP	MEDSPDIE	PROPELLR	CONT PIT	SUPSTMAT	ALUMINUM
EMEL TYP	MEDSPDIE	FIN STAB	YES	PASSAGE	PORTSTBD
		HEAT TYP	ELECTRIC		

SPECIAL PAYLOAD INPUT

WT GRP	VOL GRP	WT	VCG NU	VCG REF	AREA SUP	AREA HULL

NO SPECIAL PAYLOAD INPUT

SHIP NUMBER 2

PAYLOAD SPECIFICATIONS

QNTY	ITEM	QNTY	ITEM	QNTY	ITEM	QNTY	ITEM	QNTY	ITEM
1.00	2	1.00	204						
1.00	24	1.00	208						
1.00	27	1.00	209						
1.00	41	2.00	214						
1.00	61	4.00	215						
8.00	64	1.00	221						
1.00	65	12.00	226						
1.00	75	1.00	230						
1.00	100	1.00	232						
1.00	102	1.00	190						
1.00	116	1.00	242						
800.00	119	193.00	217						
10000.00	124	10.00	219						
1.00	131	1.00	48						
40.00	168								
2.00	180								
1.00	165								
1.00	212								
2.00	213								
6.00	200								

SUMMARY OF RESULTS

LBP	408.00	DISP FLD	3547.97	FLD DENS	16.12
BEAM	42.42	DISP LSP	2459.70	LSP DENS	11.18
DRAFT	15.96	VR LOADS	965.29	WPAY/FLD	0.10
D 0	33.89	WT MARG	122.98	WPER/FLD	0.04
D 10	25.50	WTGRP 1	1185.68	WOPS/FLD	0.43
D 20	26.71	WTGRP 2	270.56	VPAY/VOL	0.18
D AVG	35.15	WTGRP 3	166.51	VPER/VOL	0.23
LEN R DK	386.62	WTGRP 4	131.29	VOPS/VOL	0.59
CP	0.59	WTGRP 5	345.38	WTG2/SHP	15.15
CX	0.75	WTGRP 6	260.44	VMB/SHP	2.40
VCG FLD	18.39	WTGRP 7	99.84	WT3/KWIN	93.25
VCG/DAVG	0.68	VOL TOT	493040.00	WTG1/VOL	5.39
L/B	9.62	VOL HULL	382334.80	WTG5/VOL	1.57
B/H	2.66	VOL SSTR	110705.10	VHAB/MAN	517.45
EXCES KG	0.00	CRUISEKW	2201.26	WHAB/MAN	802.77
RANGE	4500.00	BATTLEKW	1739.11	MEN/DISP	0.05
SUS SHP	40000.00	24 HR KW	1286.52	KWIN/FLD	1.13
END SHP	7341.77	NU LOWSD	0.00	SHP/DISP	11.27
VSUS	30.49	NU MEDSD	4.00	DP*V/SHP	18.61
VEND	20.00	NU HI SD	0.00	WPY*V/DP	2.96
AVSEASPD	27.72	NU GT GN	0.00		
NU ACCOM	185.00	NU ST GN	0.00		
KW INST	4000.00	KW/DIESL	1000.00		
KW SPSER	4000.00	KW/GAS T	0.00		
KW EMERG	0.00	KW/STM G	0.00		

SHIP NUMBER 2
SHIP CONSTANTS

ELEMENT NUMBER	VALUE
2250	1.32
2251	1.17
2252	0.77
2253	1.11
2254	0.94
2255	0.93
2256	0.99
2257	1.42
2258	1.18
2259	1.33
2260	1.12
2261	2.23
2262	1.72
2263	3.30
2264	0.96
2265	1.72
2266	2.82
2267	1.03
2268	2.69
2269	1.65
2270	1.33
2271	1.73
2272	0.62
2273	1.10
2274	8.50
2275	0.00
2276	0.00
2277	0.00
2278	0.00
2279	0.00
2280	0.00
2281	0.00
2282	0.00
2283	0.00
2284	0.00
2285	0.00
2286	0.00
2287	0.00
2288	0.00
2289	0.00
2290	0.00
2291	0.00
2292	0.00
2293	0.00
2294	0.00
2295	0.00
2296	0.00
2297	0.00
2298	0.00
2299	0.00

SHIP NUMBER 2

DETAILED RESULTS--FUNCTIONAL GROUPING

GROUP	NAME	WEIGHT TONS	WT FRAC	VOLUME CU FT	VOL FRAC	DENSITY LBS/CU FT
100	MIL MISS	345.0	0.0973	89288.	0.1811	8.66
110	COMM/DET	70.0	0.0197	27391.	0.0556	5.72
111	RADIOCOM	16.1	0.0045	7446.	0.0151	4.84
112	RADAR	7.9	0.0022	1615.	0.0033	10.96
113	SONAR	9.3	0.0026	2015.	0.0041	10.34
114	ECM	4.5	0.0013	2295.	0.0047	4.39
115	EVALUATE	19.6	0.0055	11407.	0.0231	3.85
116	C/D SUPP	12.6	0.0035	2614.	0.0053	10.78
120	WEAPONS	163.7	0.0462	18581.	0.0377	19.73
121	GUNS	42.6	0.0120	6208.	0.0126	15.37
122	MISSILES	90.2	0.0254	8534.	0.0173	23.68
123	ASW	9.6	0.0027	935.	0.0019	23.09
124	MINE WAR	0.0	0.0000	0.	0.0000	0.00
125	SM ARMS	3.0	0.0008	765.	0.0016	8.78
126	CM NO EL	11.9	0.0034	0.	0.0000	0.00
127	WEAP SUP	6.3	0.0018	2139.	0.0043	6.64
128	SPECWEAP	0.0	0.0000	0.	0.0000	0.00
130	AVIATION	111.3	0.0314	43316.	0.0879	5.76
131	CONTROL	12.1	0.0034	2763.	0.0056	9.84
132	STOW/MNT	21.9	0.0062	34850.	0.0707	1.41
133	STORES	6.7	0.0019	3400.	0.0069	4.40
134	LIQUIDS	68.0	0.0192	2304.	0.0047	66.08
135	ORDNANCE	2.7	0.0008	0.	0.0000	0.00
140	AMPH OPS	0.0	0.0000	0.	0.0000	0.00
150	CARGO	0.0	0.0000	0.	0.0000	0.00
160	FLAG	0.0	0.0000	0.	0.0000	0.00
170	PASSNGER	0.0	0.0000	0.	0.0000	0.00
180	SPEC MIS	0.0	0.0000	0.	0.0000	0.00
200	PERSONEL	140.8	0.0397	111150.	0.2254	2.84
210	LIVING	38.3	0.0108	68265.	0.1385	1.26
211	OFF BER	0.0	0.0000	9217.	0.0187	0.00
212	OFF MESS	0.0	0.0000	3456.	0.0070	0.00
213	OFF BATH	0.0	0.0000	1034.	0.0021	0.00
214	CPO BER	0.0	0.0000	4790.	0.0097	0.00
215	CPO MESS	0.0	0.0000	1817.	0.0037	0.00
216	CPO BATH	0.0	0.0000	1297.	0.0026	0.00
217	CREW BER	0.0	0.0000	29722.	0.0603	0.00
218	CREWMESS	0.0	0.0000	11412.	0.0231	0.00
219	CREWBATH	0.0	0.0000	5520.	0.0112	0.00

SHIP NUMBER 2

DETAILED RESULTS--FUNCTIONAL GROUPING CONTINUED

GROUP	NAME	WEIGHT TONS	WT FRAC	VOLUME CU FT	VOL FRAC	DENSITY LBS/CU FT
220	SUPPORT	28.0	0.0079	27462.	0.0557	2.28
221	ADMIN FN	1.1	0.0003	1297.	0.0026	1.90
222	FOOD P&H	10.2	0.0029	7552.	0.0153	3.02
223	MED &DEN	1.3	0.0004	2824.	0.0057	1.05
224	PER SERV	8.2	0.0023	7450.	0.0151	2.47
225	REC &WEL	2.1	0.0006	6639.	0.0135	0.72
226	SEWAGE	5.0	0.0014	1700.	0.0034	6.59
230	STOWAGE	74.5	0.0210	15423.	0.0313	10.82
231	STORES	30.3	0.0085	5036.	0.0102	13.49
232	PER STOW	14.2	0.0040	4408.	0.0089	7.23
233	POTWATER	30.0	0.0084	5979.	0.0121	11.23
300	SHIP OPS	1509.4	0.4256	292602.	0.5935	11.56
310	CONTROL	36.3	0.0102	18529.	0.0376	4.39
311	SHIP CNT	27.9	0.0079	6056.	0.0123	10.31
312	DAM CONT	0.0	0.0000	2541.	0.0052	0.00
313	OFFICES	8.4	0.0024	9932.	0.0201	1.90
320	MACH SYS	557.3	0.1571	130318.	0.2643	9.58
321	MACH BOX	393.1	0.1108	96170.	0.1951	9.16
322	UPTAKES	12.7	0.0036	20190.	0.0409	1.41
323	SH,BR,PR	87.0	0.0245	0.	0.0000	0.00
324	MANEUVER	32.1	0.0091	4226.	0.0086	17.03
325	VENTILAT	32.4	0.0091	9732.	0.0197	7.45
330	DECK AUX	61.2	0.0172	15085.	0.0306	9.08
331	ANCH,M&T	39.8	0.0112	15000.	0.0304	5.94
332	UNREP	21.4	0.0060	85.	0.0002	563.95
340	MAINTAIN	46.1	0.0130	5938.	0.0120	17.41
341	MECHANIC	5.5	0.0016	3522.	0.0071	3.50
342	ELECTRIC	2.8	0.0008	1765.	0.0036	3.50
343	MISC	37.9	0.0107	651.	0.0013	130.26
350	STOWAGE	799.7	0.2255	39059.	0.0792	45.86
351	FUEL OIL	641.6	0.1809	26293.	0.0533	54.66
352	R FEED W	0.0	0.0000	0.	0.0000	0.00
353	LUBE OIL	14.3	0.0040	559.	0.0011	57.44
354	DIES OIL	83.7	0.0236	3327.	0.0067	56.33
355	MISC LIQ	0.0	0.0000	0.	0.0000	0.00
356	STOR&SUP	43.4	0.0122	8879.	0.0180	10.94
357	BOATS	16.7	0.0047	0.	0.0000	0.00

SHIP NUMBER 2

DETAILED RESULTS--FUNCTIONAL GROUPING CONTINUED

GROUP	NAME	WEIGHT TONS	WT FRAC	VOLUME CU FT	VOL FRAC	DENSITY LBS/CU FT
360	TANKAGE	0.0	0.0000	23449.	0.0476	0.00
361	BALLAST	0.0	0.0000	9000.	0.0183	0.00
362	PEAK	0.0	0.0000	1449.	0.0029	0.00
363	VOIDS	0.0	0.0000	13000.	0.0264	0.00
364	XFLOODNG	0.0	0.0000	0.	0.0000	0.00
365	MISC TNK	0.0	0.0000	0.	0.0000	0.00
370	PASS&ACC	8.9	0.0025	60225.	0.1222	0.33
380	HULL MAR	0.0	0.0000	0.	0.0000	0.00
390	SUP MARG	0.0	0.0000	0.	0.0000	0.00
400	HULL GRP	1207.3	0.3404			
410	BASCHULL	532.8	0.1502			
420	SEC HULL	552.9	0.1559			
430	DECKHOUS	121.6	0.0343			
440	ARMOR	0.0	0.0000			
450	FREEFLLQ	0.0	0.0000			
500	SHIP SYS	344.3	0.0971			
	TOTAL	3546.8	1.0000	493041.	1.0000	16.11

SHIP NUMBER 2

DETAILED RESULTS--BSCI WEIGHT LISTING

GROUP	NAME	WEIGHT TONS	WT FRAC FULL LD	WT FRAC LITE SH	VCG FT
100	PLATING	265.2	0.0747	0.1078	13.9
101	FRAMING	155.9	0.0439	0.0634	11.7
102	INN BOTM	0.0	0.0000	0.0000	4.8
103	PLATFLAT	75.5	0.0213	0.0307	13.8
104		0.0	0.0000	0.0000	0.0
105		0.0	0.0000	0.0000	0.0
106		0.0	0.0000	0.0000	0.0
107	ALL DECK	183.5	0.0517	0.0746	31.7
108		0.0	0.0000	0.0000	0.0
109		0.0	0.0000	0.0000	0.0
110		0.0	0.0000	0.0000	0.0
111	SUPERSTR	121.6	0.0343	0.0494	46.4
112	PROP FND	41.9	0.0118	0.0170	9.2
113	AUX FNDS	83.3	0.0235	0.0339	14.1
114	STR BKHD	131.8	0.0371	0.0536	18.6
115	TRK&ENCL	36.7	0.0103	0.0149	21.0
116	STR SPON	0.0	0.0000	0.0000	0.0
117	ARMOR	0.0	0.0000	0.0000	0.0
118	AC T STR	0.0	0.0000	0.0000	15.4
119	CAST&FOR	35.8	0.0101	0.0146	13.2
120	SEACHEST	1.8	0.0005	0.0007	5.2
121	BAL UNIT	0.0	0.0000	0.0000	0.0
122	SPEC DRS	0.0	0.0000	0.0000	24.8
123	DRS&HTCH	17.0	0.0048	0.0069	29.8
124		0.0	0.0000	0.0000	0.0
125	MASTKGPT	4.6	0.0013	0.0019	84.3
127	SONAR DM	2.5	0.0007	0.0010	-2.0
128	TOWRPLAT	0.0	0.0000	0.0000	0.0
150	WELDRIVT	28.5	0.0080	0.0116	20.5
151	FREEFLIQ	0.0	0.0000	0.0000	5.6
	GRP1 TOT	1185.7	0.3342	0.4820	20.9
200	BOIL&CON	0.0	0.0000	0.0000	15.3
201	PROPUNIT	111.5	0.0314	0.0453	14.0
202	MN CONDS	0.0	0.0000	0.0000	9.3
203	SH,BR,PR	87.0	0.0245	0.0354	5.0
204	COMB AIR	7.8	0.0022	0.0032	38.4
205	UPTAKES	12.7	0.0036	0.0052	58.9
206	PROP CNT	6.0	0.0017	0.0024	21.1
207	MN STM S	0.0	0.0000	0.0000	22.5
208	FW&CONDN	0.0	0.0000	0.0000	14.2
209	CIRC&CWS	3.6	0.0010	0.0014	8.8
210	FOSERSYS	8.9	0.0025	0.0036	10.9
211	LBOILSYS	11.0	0.0031	0.0045	10.8
250	REPAIRPT	5.0	0.0014	0.0020	16.5
251	OPER FLD	17.0	0.0048	0.0069	11.2
	GRP2 TOT	270.6	0.0763	0.1100	13.6

SHIP NUMBER 2

DETAILED RESULTS--BSCI WEIGHT LISTING CONTINUED

GROUP	NAME	WEIGHT TONS	WT FRAC FULL LD	WT FRAC LITE SH	VCG FT
300	EL PWGEN	96.2	0.0271	0.0391	16.7
301	POW SWBD	14.6	0.0041	0.0059	21.0
302	CABLE	35.0	0.0099	0.0142	25.6
303	LIGHTING	17.4	0.0049	0.0071	30.3
350	REPAIRPT	3.4	0.0009	0.0014	17.0
351	GEN FLDS	0.0	0.0000	0.0000	13.5
	GRP3 TOT	166.5	0.0469	0.0677	20.4
400	NAV EQUP	3.7	0.0011	0.0015	51.4
401	IC SYSTS	22.1	0.0062	0.0090	27.7
402	GFC SYST	10.0	0.0028	0.0041	49.0
403	CM NO EL	11.9	0.0034	0.0048	24.3
404	ECM	4.5	0.0013	0.0018	49.5
405	MFC SYS	0.4	0.0001	0.0002	64.0
406	ASW FCS	11.1	0.0031	0.0045	52.6
407	TORP FCS	0.0	0.0000	0.0000	0.0
408	RADAR	7.9	0.0022	0.0032	49.5
409	RADIOCOM	16.1	0.0045	0.0065	28.5
410	ELEC NAV	2.0	0.0006	0.0008	55.0
411	SPACTRCK	0.0	0.0000	0.0000	0.0
412	SONAR	9.3	0.0026	0.0038	17.5
413	ELEC TDS	19.6	0.0055	0.0080	43.0
415	ELECTEST	0.0	0.0000	0.0000	0.0
450	REPAIRPT	4.6	0.0013	0.0019	28.9
451	CC OPFLD	8.0	0.0023	0.0033	-3.0
	GRP4 TOT	131.3	0.0370	0.0534	34.2
500	HEAT SYS	12.7	0.0036	0.0051	13.1
501	VENT SYS	40.5	0.0114	0.0165	33.5
502	AIR COND	22.0	0.0062	0.0090	20.6
503	REFER PL	7.5	0.0021	0.0030	16.4
504	HEAF,ETC	5.6	0.0016	0.0023	21.0
505	PLUMBING	7.4	0.0021	0.0030	27.4
506	FIREMAIN	29.9	0.0084	0.0121	24.8
507	FIRE EXT	8.0	0.0023	0.0033	27.5
508	BALSTSYS	11.4	0.0032	0.0047	10.2
509	FRESHWAT	13.3	0.0038	0.0054	22.9
510	SCUPPERS	2.3	0.0007	0.0009	32.1
511	FUELTRAN	22.2	0.0063	0.0090	13.1
512	TANKHEAT	0.0	0.0000	0.0000	5.9
513	COMP AIR	22.7	0.0064	0.0092	16.4
514	AUX STM	0.0	0.0000	0.0000	12.3
515	BUOY CNT	0.0	0.0000	0.0000	0.0
516	MISCPIPE	0.0	0.0000	0.0000	10.5
517	DISTILLG	5.6	0.0016	0.0023	17.6
518	STEERING	11.2	0.0032	0.0046	15.8
519	RUDDERS	20.9	0.0059	0.0085	12.7
520	ANCH,M&T	28.0	0.0079	0.0114	25.1

SHIP NUMBER 2

DETAILED RESULTS--BSCI WEIGHT LISTING CONTINUED

GROUP	NAME	WEIGHT TONS	WT FRAC FULL LD	WT FRAC LITE SH	VCG FT
521	STOR EQP	4.9	0.0014	0.0020	37.7
522	ELOPGEAR	0.0	0.0000	0.0000	0.0
523	AIR ELEV	0.0	0.0000	0.0000	0.0
524	ACARGEAR	4.0	0.0011	0.0016	34.0
525	CATS&JBD	0.0	0.0000	0.0000	0.0
526	HYDROFLS	0.0	0.0000	0.0000	0.0
527	STAB FIN	24.7	0.0070	0.0100	7.8
528	UNREP	21.4	0.0060	0.0087	34.0
550	REPAIRPT	3.5	0.0010	0.0014	18.1
551	AUX FLDS	15.6	0.0044	0.0064	19.8
	GRP5 TOT	345.4	0.0973	0.1404	21.4
600	HULL FIT	11.8	0.0033	0.0048	38.3
601	BOATS	16.7	0.0047	0.0068	44.0
602	RIG&CANV	1.0	0.0003	0.0004	45.6
603	LAD&GRAT	26.6	0.0075	0.0108	17.7
604	NONS B&D	19.3	0.0054	0.0079	32.7
605	PAINTING	35.9	0.0101	0.0146	22.2
606	DK COVER	14.5	0.0041	0.0059	29.7
607	HULL INS	38.0	0.0107	0.0154	29.2
608	STORERMS	32.6	0.0092	0.0133	22.8
609	UTIL EQP	8.2	0.0023	0.0033	26.1
610	WKSP EQP	9.3	0.0026	0.0038	27.5
611	GALY EQP	10.2	0.0029	0.0041	31.4
612	LIV FURN	21.6	0.0061	0.0088	29.1
613	OFF FURN	11.9	0.0033	0.0048	35.3
614	M&D FURN	1.3	0.0004	0.0005	29.5
615	RAD SHLD	0.0	0.0000	0.0000	0.0
650	REPAIRPT	1.7	0.0005	0.0007	24.1
651	O&F FLDS	0.0	0.0000	0.0000	0.0
	GRP6 TOT	260.4	0.0734	0.1059	28.1
700	GUN MNTS	17.5	0.0049	0.0071	44.0
701		0.0	0.0000	0.0000	0.0
702		0.0	0.0000	0.0000	0.0
703	SPWEPH&S	0.0	0.0000	0.0000	0.0
704	MIS LH&S	66.0	0.0186	0.0268	31.0
705		0.0	0.0000	0.0000	0.0
706		0.0	0.0000	0.0000	0.0
707		0.0	0.0000	0.0000	0.0
708	TORPTH&S	7.0	0.0020	0.0028	37.0
709		0.0	0.0000	0.0000	0.0
710	MINE H&S	0.0	0.0000	0.0000	0.0
711	SM ARMS	3.0	0.0008	0.0012	34.0
712	AIR H&ST	0.0	0.0000	0.0000	0.0
713		0.0	0.0000	0.0000	0.0
720	CARGOH&S	0.0	0.0000	0.0000	0.0
750	REPAIRPT	5.6	0.0016	0.0023	20.0
751	ARM FLDS	0.7	0.0002	0.0003	32.7
	GRP7 TOT	99.8	0.0281	0.0406	33.2

SHIP NUMBER 2

DETAILED RESULTS--BSCI WEIGHT LISTING CONTINUED

GROUP	NAME	WEIGHT TONS	WT FRAC FULL LD	VCG FT
800	SHIP OCE	20.7	0.0058	25.5
801	TRPS&EFF	0.0	0.0000	25.5
802	PASS&EFF	0.0	0.0000	25.5
803	SHIPAMMO	41.4	0.0117	27.9
804	AV AMMO	2.7	0.0008	36.0
805	AIRCRAFT	17.9	0.0050	41.0
806	PROV&PST	30.3	0.0085	17.2
807	GEN STOR	8.1	0.0023	23.2
808	MARINEST	0.0	0.0000	0.0
809	AERO STR	6.7	0.0019	27.2
810	ORDSTRSH	0.0	0.0000	0.0
811	ORDSTRAV	0.0	0.0000	0.0
812	POTWATER	30.0	0.0084	4.2
813	R FEED W	0.0	0.0000	4.7
814	LUBOILSH	14.3	0.0040	16.2
815	LUBOILAV	3.7	0.0010	10.2
816	FUEL OIL	641.6	0.1808	8.3
817	DIES OIL	83.7	0.0236	12.5
818	GASOLINE	0.0	0.0000	0.0
819	JP-5	64.3	0.0181	11.2
820	MISC LIQ	0.0	0.0000	0.0
821	CARGO	0.0	0.0000	0.0
822	BALL WAT	0.0	0.0000	0.0
	VRLOAD TOT	965.3	0.2721	11.3
	LIGHT SHIP	2459.7	0.6933	22.1
	WT MARGIN	123.0	0.0347	22.0
	FULL LOAD DISP	3548.0	1.0000	18.4

DETAILED RESULTS--FUNCTIONAL ELECTRIC LOADS

GROUP	NAME	CRUISE KW	BATTLE KW	24 HR AVG KW
100	PA&STEER	122.3	126.6	131.9
200	AUX MACH	202.5	250.2	169.3
300	DECKMACH	2.0	1.5	0.3
400	SHOPS	6.9	1.2	5.4
500	IC&ELEX	197.9	219.1	184.1
600	ORDN SYS	25.6	102.9	12.1
700	HOTEL	119.3	92.8	139.4
800	A/C&VENT	786.8	328.8	247.7
900	PWR CONV	110.0	214.6	99.4
	ELECMARG	508.0	401.3	296.9
	TOTAL KW	2201.3	1739.1	1286.5

APPENDIX C

CLASSIFICATION SYSTEMS

APPENDIX C

CLASSIFICATION SYSTEMS

The classification systems used to identify functional and weight groups are given in this appendix. Table 22 is the functional classification system developed for the model. Table 23 gives the BSCI weight groups as modified for use in the model.

Although the Ship Work Breakdown Structure (SWBS) described in Reference (20) is the system currently used to classify weight groups for ships in the U. S. Navy, the BSCI classification system was chosen for use in this thesis. There were two reasons for choosing the BSCI system. First, most of the sample ships weight data was in the BSCI format. Secondly, at the three-digit weight breakdown level, SWBS data can be readily converted to BSCI format; however, BSCI data at the same level of detail cannot easily be converted to SWBS format. This is because the SWBS format is in the finer level of detail at the three-digit level.

TABLE 22

FUNCTIONAL CLASSIFICATION SYSTEM

ITEM NUMBER	FUNCTIONAL NAME	U.S. NAVY SHIP SPACE CLASSIFICATION SYSTEM NUMBER (Reference 17)	NAVSHIPS B.S.C.I. WEIGHT Group (1965)*
100	MILITARY MISSION (Payload)	Group 1	
110	COMMUNICATIONS, DETECTION & EVALUATION	1.1	
111	Radio, Signal, Secure Comms, Lookout	1.111, 1.112 1.113, 1.114	409
112	Radar	1.115	408
113	Sonar	1.116	412
114	Electronic Countermeasures	1.117	404
115	Evaluation	1.118	413
116	Comms, Detection, Evaluation Support	1.12	415, 450, 451
120	WEAPONS	1.2	
121	Guns	1.21	402, 700, 873
122	Missiles	1.22	405, 774, 883
123	ASW	1.23, 1.24	486, 784, 708, 893
124	Mines	1.25	710
125	Small arms, pyrotechnics	1.26	711
126	Countermeasures	1.27	403
127	Weapons Support	1.28	750, 751, 810
128	Nuclear Weapons	1.29	615, 703
130	AVIATION	1.3	
131	Operations & Control	1.31	496, 613**
132	Aircraft Stowage, Handling & Maintenance	1.32, 1.33, 1.34	523, 524, 525, 805
133	Aviation Stores	1.35	809, 811
134	Aviation Liquids	1.36	815, 819
135	Aviation Ordnance	1.37	712, 804
140	AMPHIBIOUS WARFARE	1.4	801, 808
150	CARGO TRANSPORT	1.5	720, 821

*Modification to the 1965 B.S.C.I. Weight Groups are found in Table 23.
**Weight applied to more than one functional grouping.

TABLE 22 (continued)

ITEM NUMBER	FUNCTIONAL NAME	U.S. NAVY SHIP SPACE CLASSIFICATION SYSTEM NUMBER (Reference 17)	NAVSHIPS B.S.C.I. WEIGHT Group (1965)*
160	FLAG	1.6	800**
170	PASSENGER	1.7	802
180	SPECIAL MISSIONS	1.8	529
200	PERSONNEL	Group 2	
210	LIVING	2.1	612**, 505**, 800**
211	Officer Berthing	2.111	
212	Officer Messing	2.112	
213	Officer Bath	2.113	
214	CPO Berthing	2.121	
215	CPO Messing	2.122	
216	CPO Bath	2.123	
217	Crew Berthing	2.131	
218	Crew Messing	2.132	
219	Crew Bath	2.133	
220	SUPPORT	2.2	
221	Administration	2.21	613**
222	Food Preparation & Handling	2.22	611
223	Medical & Dental	2.23	614
224	Personnel Services	2.24	609
225	Recreation & Welfare	2.25	612**
226	Sewage	2.26	594
230	STOWAGE	2.3	
231	Personnel Stores (Provisions)	2.31	806
232	Personnel Stowage	2.32	608**, 800**
233	Potable Water	2.33	812
300	SHIP OPERATIONS	Group 3	
310	CONTROL	3.1	
311	Ship Control	3.11	400, 401, 410, 411
312	Damage Control	3.13	
313	Offices	3.14	613**
320	MACHINERY SYSTEMS	3.2, 3.31, 3.33	

TABLE 22 (continued)

ITEM NUMBER	FUNCTIONAL NAME	U.S. NAVY SHIP SPACE CLASSIFICATION SYSTEM NUMBER (Reference 17)	NAVSHIPS B.S.C.I. WEIGHT Group (1965)*
321	Machinery Box	3.21, 3.22, 3.23, 3.24, 3.25, 3.27, 3.12, 3.31, 3.33	200, 201, 202, 204, 206, 207, 208, 209, 210, 211, 251, 300, 301, 351, 502, 503, 504**, 512, 513, 514, 517, 527, 551, 603**
322	Uptakes	3.26	205
323	Shafting, Bearings & Propellers	3.28	203
324	Maneuvering	3.311	518, 519
325	Ventilation	3.313	501**
330	DECK AUXILIARIES	3.32	
331	Anchor Handling, Mooring & Towing	3.321, 3.322	520, 600
332	Underway Replenishment	3.323	528
340	MAINTENANCE	3.4	
341	Mechanical	3.41	610**
342	Electrical	3.42	610**
343	Miscellaneous	3.43	610**, 602, 605
350	STOWAGE	3.5	
351	Fuel Oil	3.511	816
351	Reserve Feed Water	3.512	813
353	Lube Oil	3.513	814
354	Diesel Oil	3.511	817
355	Misc. Liquid	3.514	818, 820
356	Stores & Supplies	3.52	608**, 250, 350, 550, 650, 807
357	Boats	3.53	601
360	TANKAGE	3.6	
361	Ballast	3.61	822
362	Peak Tanks	3.62	
363	Voids	3.64	
364	Cross Flooding	3.65	
365	Misc. Tanks	3.63	
370	PASSAGEWAYS & ACCESS	3.7	603**

TABLE 22 (continued)

ITEM NUMBER	FUNCTIONAL NAME	U.S. NAVY SHIP SPACE CLASSIFICATION SYSTEM NUMBER (Reference 17)	NAVSHIPS B.S.C.I. WEIGHT Group (1965)*
380	HULL MARGIN		
390	SUPERSTRUCTURE MARGIN		
400	HULL	Group 4	
410	Bsic Hull Structure		100, 101, 107**, 150**
420	Secondary Structures		116, 122, 123, 125, 127, 128, 150**, 510, 604, 113, 107**, 102, 103, 112, 114, 115, 118, 119, 120, 121
430	Deckhouse Structure		111
440	Armor		117
450	Free Flooding Liquids		151
500	SHIP SYSTEMS		302, 303, 500, 506, 507, 501**, 508, 511, 516, 521, 522, 526, 606, 607, 651, 825, 509, 505**

TABLE 23

MODIFIED BSCI WEIGHT GROUPS

Sub Group	Description
Hull Structure--Group 1	
100	Shell Plating
101	Longitudinal & Transverse Framing
102	Inner Bottom Plating
103	Platforms & Flats
107	All Decks (BSCI 104 thru 110)
111	Superstructure
112	Propulsion Foundations
113	Foundations for Aux. & Other Equip.
114	Structural Bulkheads
115	Trunks & Enclosures
116	Structural Sponsons
117	Armor
118	Aircraft Saddle Tank Structure
119	Castings & Forgings
120	Sea Chests
121	Ballast & Buoyancy Units
122	Special Doors & Closures
123	Doors & Hatches (BSCI 123 & 124)
125	Masts & Kingposts
127	Sonar Domes
128	Towers & Platforms
150	Welding, Riveting & Fastenings
151	Free Flooding Liquids
Propulsion--Group 2	
200	Boilers and Energy Converters (Includes Nuclear)
201	Propulsion Units
202	Main Condensers & Air Ejectors
203	Shafting, Bearings & Propellers
204	Combustion Air Supply
205	Uptakes & Smoke Pipes
206	Propulsion Control Equipment
207	Main Steam System
208	Feed Water & Condensate System
209	Circulating & Cooling Water System
210	Fuel Oil Service Systems
211	Lubricating Oil System
250	Propulsion Repair Parts
251	Propulsion Operating Fluids
Electric Plant--Group 3	
300	Electric Power Generation

TABLE 23 (continued)

Sub Group	Description
301	Power Distribution Switchboards
302	Power Distribution System (Cable)
303	Lighting System
350	Electric Plant Repair Parts
351	Electric Power Generator Fluids
Communication and Control--Group 4	
400	Navigation Equipment
401	Interior Communication Systems
402	Gun Fire Control Systems
403	Countermeasure System (Non-Electronic)
404	Electronic Countermeasure Systems (ECM)
405	Missile Fire Control Systems
406	ASW Fire Control & Torpedo Fire Control System
407	Torpedo Fire Control System--Submarines
408	Radar Systems
409	Radio Communication Systems
410	Electronic Navigation Systems
411	Space Vehicle Electronic Tracking Systems
412	Sonar Systems
413	Electronic Tactical Data Systems
415	Electronic Test, Checkout & Monitoring Equipment
450	Communication and Control Repair Parts
451	Communication and Control Operating Fluids
Auxiliary Systems--Group 5	
500	Heating System
501	Ventilation System
502	Air Conditioning System
503	Refrigerating Spaces, Plant & Equipment
504	Gas, HEAF, All Liquid Cargo Piping, Aviation Lube Oil System, Sewage System
505	Plumbing Installations
506	Firemain, Flushing, Sprinkler, S.W. Service Systems
507	Fire Extinguishing System
508	Drainage, Ballast, Stabilizing Tank System

TABLE 23 (continued)

Sub Group	Description
509	Fresh Water System
510	Scuppers and Deck Drains
511	Fuel & Diesel Oil Filling, Venting, Stowage & Transfer System
512	Tank Heating Systems
513	Compressed Air Systems
514	Auxiliary Steam, Exhaust Steam & Steam Drains
515	Buoyancy Control System, Submarines
516	Miscellaneous Piping Systems
517	Distilling Plant
518	Steering Systems
519	Rudders
520	Mooring, Towing, Anchor & Aircraft, Handling System & Deck Machinery
521	Elevators, Moving Stairways, Stores Handling Systems
522	Operating Gear for Retracting & Elevating Units
523	Aircrafts Elevators
524	Aircraft Arresting Gear, Barriers & Barricades
525	Catapults and Jet Blast Deflectors
526	Hydrofoils
527	Diving Planes & Stabilizing Fins
528	Replenishment at Sea & Cargo Handling
550	Auxiliary Systems Repair Parts
551	Auxiliary Systems Operating Fluids
Outfit and Furnishings--Group 6	
600	Hull Fittings
601	Boats, Boat Stowage & Handling
602	Rigging & Canvas
603	Ladders & Gratings
604	Nonstructural Bulkheads & Doors
605	Painting
606	Deck Covering
607	Hull Insulation
608	Storerooms, Stowages & Lockers
609	Equipment for Utility Spaces
610	Equipment for Workshops, Labs & Test Areas
611	Equipment for Galley, Pantry, Scullery & Commissary Outfit
612	Furnishings for Living Spaces
613	Furnishings for Offices, Control Centers & Machinery Spaces

TABLE 23 (continued)

Sub Group	Description
614	Furnishings for Medical, Dental Spaces
615	Radiation Shielding
650	Outfit & Furnishings, Repair Parts
651	Outfit & Furnishings, Operating Fluids
Armament--Group 7	
700	Guns, Gun Mounts, Ammo Handling & Storage (BSCI 700, 701, 702)
703	Special Weapons Handling & Stowage
704	Rocket & Missile Launching, Handling & Stowage Devices (BSCI 704, 705, 706, 707)
708	Torpedo Tubes, Torpedo Handling & Stowage
710	Mine Handling Systems & Stowage
711	Small arms & Pyrotechnic Stowage
712	Air Launched Weapons Handling & Stowage (BSCI 712, 713)
720	Cargo Munitions Handling & Stowage
750	Armament Repair Parts
751	Armament Operating Fluids
Loads--Group 8	
800	Ships Officers, Crew & Effects
801	Troops & Effects
802	Passengers & Effects
803	Ships Ammo
804	Aviation Ammo
805	Aircraft
806	Provisions and Personnel Stores
807	General Stores
808	Marines Stores
809	Aero Stores
810	Ordnance Stores Ship
811	Ordnance Stores AV
812	Potable Water
813	Reserve Feed Water
814	Lube Oil Ship
815	Lube Oil Aviation
816	Fuel Oil
817	Diesel Oil
818	Gasoline
819	JP-5
820	Miscellaneous Liquids

TABLE 23 (continued)

Sub Group	Description
821	Cargo
822	Ballast Water
825	Future Development Margin

APPENDIX D

DERIVED EQUATIONS LISTING

APPENDIX D

DERIVED EQUATIONS LISTING

This appendix provides a listing of the equations which were derived to provide the standard calculations required by the computer program. The data used were taken from References (1), (4), (6), (9), (10), (12), (14), (16), (21), (22), and (23).

The technique used to develop most of the relationships listed in this appendix was linear regression for two variables by the method of least squares. In each case several combinations of variables were tried to determine which gave the best correlation. A coefficient of determination was calculated for each try to give an indication of how closely the equation fit the data. Data points available for each calculation were examined in an effort to insure that only appropriate ship values were used in deriving a particular equation.

In a few instances equations were developed to best fit existing curves, e.g., linear approximations to the powering worm curve used in horsepower calculations. Also, in a few cases where insufficient data was available or a satisfactory variable correlation could not be attained, an average value was selected as the value to be used.

Starting Estimates

$DPTRY = 0.00076\ LBP^{2.57}$	LBP input item
$DPTRY = 7.0754\ WPAYIN + 914.45$	LBP not input item
$KGTRY = 0.1589\ LBP^{.7771}$	

Ship Geometry

$C_{wp} = 0.425\ C_B + 0.526$

$C_{\alpha} = 0.0733\ C_p + 0.0026$

Speed/Power

$VMAX = 8.696(SHP/LBP)^{.2668}$	
$EHPAPP = 1.3\ EHPBH$	$SLRAT \leq 0.85$
$EHPAPP = (1.4587 - 0.1867\ SLRAT)EHPBH$	$0.85 < SLRAT \leq 1.6$
$EHPAPP = (1.310 - 0.0938\ SLRAT)EHPBH$	$1.6 < SLRAT \leq 1.92$
$EHPAPP = 1.13\ EHPBH$	$SLRAT > 1.92$
$EHP = 1.1\ EHPAPP$	$SLRAT \leq 0.70$
$EHP = (1.205 - 0.150\ SLRAT)EHPAPP$	$0.70 < SLRAT \leq 0.82$
$EHP = (1.3827 - 0.3667\ SLRAT)EHPAPP$	$0.82 < SLRAT \leq 1.18$
$EHP = (1.1109 - 0.1364\ SLRAT)EHPAPP$	$1.18 < SLRAT \leq 1.4$
$EHP = (0.9753 - 0.0395\ SLRAT)EHPAPP$	$1.4 < SLRAT \leq 1.78$
$EHP = (0.8645 + 0.0227\ SLRAT)EHPAPP$	$SLRAT > 1.78$

Electric Loads

Cruise KW Loads

$ECR(1) = (0.00173FLDISP \times VSUS - 64.62)A$

$ECR(2) = (0.0517FLDISP + 19.27)E$

$ECR(3) = 2.0$

$ECR(4) = 6.9$

$ECR(5) = 0.2041WGP4 + 172.71$

ECR(6) = 25.6

ECR(7) = 0.0169FLDISP + 59.38

ECR(8) = 0.1649FLDISP - 344.33 Steam heat

ECR(8) = 0.1320FLDISP + 438.96 Electric heat

ECR(9) = 110.0

A = 1.0; E = 1.0 Any propulsion plant except nuclear

A = 4.0; E = 2.0 Nuclear propulsion plant

Battle KW Loads

EBT(1) = (0.00209FLDISP x VSUS - 99.19)A

EBT(2) = (0.0746FLDISP - 14.21)E

EBT(3) = 1.5

EBT(4) = 1.2

EBT(5) = 0.3613WGP4 + 174.52

EBT(6) = 1.670WTGP7 - 63.79

EBT(7) = 0.00794FLDISP + 64.70

EBT(8) = 0.0382FLDISP + 193.40

EBT(9) = 214.6

A = 1.0; E = 1.0 Any propulsion plant except nuclear

A = 4.0; E = 2.0 Nuclear propulsion plant

24 Hour KW Average Loads

EAV(1) = (0.00115FLDISP x VSUS + 7.63)A

EAV(2) = (0.0705FLDISP - 80.54)E

EAV(3) = 0.3

EAV(4) = 5.4

EAV(5) = 0.3322WGP4 + 143.17

EAV(6) = 12.1

EAV(7) = 0.00462FLDISP + 123.03

EAV(8) = 0.1021FLDISP - 114.19 Steam heat

EAV(8) = 0.1252FLDISP + 343.10 Electric heat

EAV(9) = 99.4

A = 1.0; E = 1.0 Any propulsion plant except nuclear

A = 4.0; E = 2.0 Nuclear propulsion plant

<u>Machinery Box Minimum Depth</u>

DEPMB = CVK + HCOR + HABCVK

CVK = 0.2B - 6.0

HCOR = $-10.0C_x + 9.0$

HABCVK = 0.00025SHP/NSHFT + 20.5	PPTYP = 1,2,3,4 NB/NSHFT = 1
HABCVK = 0.000125SHP/NSHFT + 20.0	PPTYP = 1,2,3,4 NB/NSHFT > 1
HABCVK = 19.0	PPTYP = 5,6,7,8 NSHFT = 1
HABCVK = 21.5	PPTYP = 5,6,7,8 NSHFT > 1

<u>Weight (BSCI Groups Modified)</u>

Hull Structure--Group 1

W(100) = (0.0677 FLDISP + 25.26)C

W(101) = (0.0532 FLDISP - 55.38)C

W(102) = 0.0 FLDISP $\leq$ 4600

W(102) = (0.0120 FLDISP + 9.27)C FLDISP > 4600

W(103) = $(0.00581\ \mathrm{FLDISP}^{1.159})\mathrm{C}$

W(107) = (0.0694 FLDISP - 62.51)C

W(111) = $0.00778\ \mathrm{VOLSST}^{0.820}$ Aluminum superstructure

W(111) = 0.00199 VOLSST - 16.44 Steel superstructure

W(112) = (0.00101SHP/(NB x NSHFT) - 3.51)NB x NSHFT x C PPTYP = 2

$W(112) = (0.5428\ SHP^{0.3348})C$ PPTYP = 1

$W(112) = (0.00204SHP)C$ PPTYP = 7

$W(112) = (0.000818SHP/(NR \times NSHFT) + 40.65)NR \times NSHFT \times C$ PPTYP = 4

$W(112) = (0.000239SHP/(NE \times NSHFT) + 16.18)NE \times NSHFT \times C$

PPTYP = 5,6,8

$W(112) = (0.000714SHP)C$ PPTYP = 3

$W(113) = (0.000189\ VOLHUL - 11.68)C$

$W(114) = (0.000285\ VOLHUL + 22.83)C$ NON Nuclear Propulsion

$W(114) = (0.000658\ VOLHUL - 115.89)C$ Nuclear propulsion

$W(115) = 0.0000527\ VOLTOT - 4.47$

W(116) = Input Item

W(117) = Input Item

W(118) = Input Item

$W(119) = (0.0000708\ VOLTOT + 0.94)C$

$W(120) = 3.03 \times 10^{-8} VOLMB^{1.56}$ PPTYP = 5,6,7,8

$W(120) = 8.42 \times 10^{-8} VOLMB^{1.53}$ PPTYP = 1,2,3,4

W(121) = Input Item

$W(122) = 0.0$ $FLDISP < 7600$

$W(122) = 0.00342FLDISP - 18.51$ $FLDISP \geq 7600$

$W(123) = 0.0000383VOLTOT - 1.89$

$W(125) = 0.000278FLDISP + 3.62$

W(127) = Input Item

W(128) = Input Item

$W(150) = (0.000527VOLTOT^{0.8314})C$

W(151) = Input Item

$C = 1.0$ Steel Hull

$C = 0.55$ Aluminum Hull

$W(200) = 0.0$	PPTYP = 5,6,7
$W(200) = 0.00234SHP + 48.09$	PPTYP = 2
$W(200) = 0.000883SHP$	PPTYP = 8
$W(200) = 0.00288SHP + 21.92$	PPTYP = 1
$W(200) = 0.00234SHP - 14.00$	PPTYP = 3
$W(200) = 0.000183SHP^{1.456}$	PPTYP = 4
$W(201) = 0.00143SHP + 17.92$	PPTYP = 2,3
$W(201) = 0.00175SHP + 13.25$	PPTYP = 1
$W(201) = 0.000761SHP^{1.119}$	PPTYP = 4
$W(201) = 0.0124SHP + 5.25$	PPTYP = 7
$W(201) = 0.00283SHP + 2.68$	PPTYP = 5,6
$W(201) = 0.00247SHP$	PPTYP = 8
$W(202) = 0.0$	PPTYP = 5,6,7
$W(202) = 0.000766SHP + 2.98$	PPTYP = 1
$W(202) = 0.000457SHP + 2.57$	PPTYP = 2,3
$W(202) = 0.00923SHP^{0.7935}$	PPTYP = 4
$W(202) = 0.000533SHP$	PPTYP = 8

$W(203) = WSHAFT + WPROP + WBRGS$

$WSHAFT = F \times LBP \times NSHFT(0.0275(SHP/(NSHFT \times RPM))^{2/3})^{0.8768}$

Solid Shaft

$WSHAFT = F \times LBP \times NSHFT(0.0134(SHP/(NSHFT \times RPM))^{2/3})^{0.9497}$

Hollow Shaft, Fixed Pitch Prop.

$$WSHAFT = F \times LBP \times NSHFT(1 + .5NSHFT) \times (0.0134(SHP/(NSHFT \times RPM))^{2/3})^{0.9497}$$

Hollow Shaft, Controllable Pitch Prop.

$RPM = 96.12VSUS/DPROP + 52.15$

$DPROP = 2.603H^{0.629}$	One Shaft	
$DPROP = 4.281H^{0.4283}$	Two Shafts	
F = 0.36	PPTYP = 1,2,3,4	
F = 0.20	PPTYP = 5,6,7,8	
$WPROP = (0.00146DPROP^{3.279})NSHFT$	Fixed Pitch Prop.	
$WPROP = (0.00314DPROP^{3.128})NSHFT$	Controllable Pitch Prop.	
WBRGS = 0.15(WSHAFT + WPROP)		
W(204) = 0.0	PPTYP = 4,7	
W(204) = 0.000119SHP + 12.22	PPTYP = 2	
W(204) = 0.000119SHP + 10.14	PPTYP = 3	
W(204) = 0.000105SHP + 6.50	PPTYP = 1	
W(204) = 0.000196SHP	PPTYP = 5,6	SSETYP = 4,5,6
$W(204) = 0.000503(SHP + \frac{KWINST}{.8 \times .746})$	PPTYP = 5,6	SSETYP = 2,3
W(204) = 0.000267SHP	PPTYP = 8	
W(205) = 0.0	PPTYP = 4	
W(205) = 0.000317SHP	PPTYP = 5,6,8	SSETYP = 4,5,6
$W(205) = 0.00140(SHP + \frac{KWINST}{.8 \times .746})$	PPTYP = 5,6,8	SSETYP = 2,3
W(205) = 0.00209SHP	PPTYP = 7	
W(205) = 0.000181SHP + 3.18	PPTYP = 1	
W(205) = 0.000136SHP + 14.14	PPTYP = 2	
W(205) = 0.000136SHP + 6.54	PPTYP = 3	
W(206) = 0.000500SHP	PPTYP = 8	
W(206) = 4.0 NSHFT	PPTYP = 1,2,3,4	
W(206) = 0.00144SHP	PPTYP = 7	
W(206) = 0.0000525SHP + 3.90	PPTYP = 5,6	
W(207) = 0.0	PPTYP = 5,6,7	
W(207) = 0.0000833SHP	PPTYP = 8	

$W(207) = 0.000544SHP - 1.70$ PPTYP = 2,3

$W(207) = 0.000586SHP - 5.68$ PPTYP = 1

$W(207) = 33.52SHP^{0.0392}$ PPTYP = 4

$W(208) = 0.0$ PPTYP = 5,6,7

$W(208) = 0.0001833SHP$ PPTYP = 8

$W(208) = 2.592SHP^{0.3105}$ PPTYP = 4

$W(208) = 0.000610SHP + 10.42$ PPTYP = 2,3

$W(208) = 0.000564SHP + 7.48$ PPTYP = 1

$W(209) = 0.0$ PPTYP = 5,6 SSETYP = 2,3

$W(209) = 0.000890KWINST$ PPTYP = 5,6 SSETYP = 4,5,6

$W(209) = 0.00111(SHP + \frac{KWINST}{.8 \times .746})$ PPTYP = 7

$W(209) = 1.32 \times 10^{-8}(SHP + \frac{KWINST}{.8 \times .746})^{1.8642}$ PPTYP = 4

$W(209) = 0.000192(SHP + \frac{KWINST}{.8 \times .746}) + 4.02$ PPTYP = 1,2,3

$W(209) = 0.000300SHP$ PPTYP = 8

$W(210) = 0.0$ PPTYP = 4

$W(210) = 0.00882W(816) + 3.25$ PPTYP = 1,2,3,5,6,8

$W(210) = 0.00882W(817) + 3.25$ PPTYP = 7

$W(211) = 0.000267SHP$ PPTYP = 8

$W(211) = 0.000156SHP + 4.82$ PPTYP = 1,2,3

$W(211) = 0.0443SHP^{0.560}$ PPTYP = 4

$W(211) = 3.10 \times 10^{-7}SHP^{1.641}$ PPTYP = 5,6

$W(211) = 0.00193SHP$ PPTYP = 7

$W(250) = 45.0$ PPTYP = 4

$W(250) = 5.0$ PPTYP = 1,2,3,5,6,7,8

NSHFT = 1

$W(250) = 10.0$ PPTYP = 1,2,3,5,6,7,8

NSHFT = 2

$W(251) = 0.000668SHP + 12.14$ PPTYP = 1,2,3

$W(251) = 0.0972(W(200) + W(201) + W(202) + W(207) + W(208) + W(209) + W(211)) - 69.57$ PPTYP = 4

$W(251) = 1.152(W(209) + W(210) + W(211)) - 10.10$ PPTYP = 5,6

$W(251) = 0.618(W(209) + W(210) + W(211))$ PPTYP = 7

$W(251) = 0.000633SHP$ PPTYP = 8

Electric Plant--Group 3

$W(300) = NLSD(0.0424KWPRD + 0.44) + NMSD(0.0240KWPRD + 0.05) + NHSD(0.0137KWPRD + 0.32) + NGTG(0.00424KWPRGT + 16.4) + NSTG(0.0167KWPRSG - 1.63)$

$W(301) = 0.00300KWINST + 2.61$

$W(302) = 2.15 \times 10^{-8} VOLTOT^{1.623}$ $VOLTOT < 400{,}000$

$W(302) = 0.000170VOLTOT - 48.83$ $VOLTOT \geq 400{,}000$

$W(303) = 0.0000367VOLTOT - 0.73$

$W(350) = 0.000348KWINST + 1.96$

W(351) = Input Item

Communication and Control--Group 4

$W(400) = 0.000350V(311) + 1.62$

$W(401) = 0.0000508VOLTOT - 2.90$

W(402) = Input Item

$W(403) = 0.00333FLDISP + 0.12$

W(404) = Input Item

W(405) = Input Item

$W(406) = W(486) + W(496)$

W(486) = Input Item

W(496) = Input Item

W(407) = 0.0

W(408) = Input Item

W(409) = Input Item

W(410) = 2.0

W(411) = Input Item

W(412) = Input Item

W(413) = Input Item

W(415) = Input Item

W(450) = 0.0317(W(400)+ W(401) + •••W(413) + W(415)) + 0.82

W(451) = Input Item

Auxiliary Systems--Group 5

W(500) = 7.72×10^{-8}VOLTOT$^{1.443}$	Electric heat
W(500) = 0.0000110VOLTOT + 0.76	Steam heat

W(501) = 0.0000728VOLTOT + 4.57

W(502) = 0.0000346VOLTOT + 4.96

W(503) = 0.0205NACC + 3.66

W(504) = 0.000728FLDISP - 1.98 +W(594)

W(594) = Input Item

W(505) = 0.00107(V(213) + V(216) + V(219)) - 0.96

W(506) = 0.0000471VOLTOT + 6.63

W(507) = 0.000619VOLTOT$^{0.7224}$

W(508) = 0.0000243VOLHUL + 2.15

W(509) = 0.00170V(233) + 3.18

W(510) = 0.00756LBP - 0.75

W(511) = 0.0	PPTYP = 4
W(511) = 0.0276W(816) + 4.50	PPTYP = 1,2,3,5,6,8
W(511) = 0.0276W(817) + 4.50	PPTYP = 7

$W(512) = 0.00323W(816) + 1.01$	PPTYP = 1,2
$W(512) = 0.0$	PPTYP = 3,4,5,6,7,8
$W(513) = 0.0000959V(321) - 4.50$	PPTYP = 1,2,4
$W(513) = 0.00132SHP$	PPTYP = 7
$W(513) = 0.000426SHP$	PPTYP = 3
$W(513) = 0.000274SHP + 11.78$	PPTYP = 5,6,8
$W(514) = 0.000667SHP^{1.406}$	PPTYP = 1,2,3,4
$W(514) = 0.0000120VOLTOT$	PPTYP = 5,6,7,8 Steam heat
$W(514) = 0.0$	PPTYP = 5,6,7,8 Electric heat
$W(515) = 0.0$	
$W(516) = 0.0$	PPTYP = 1,2,3,5,6,7,8
$W(516) = 20.0$	PPTYP = 4
$W(517) = 0.0000944V(321) - 0.86$	PPTYP = 1,2,3
$W(517) = 0.0783NACC^{0.8847}$	PPTYP = 4
$W(517) = 0.0172NACC + 2.37$	PPTYP = 5,6,7,8
$W(518) = 0.0000681FLDISP \times VSUS + 3.89$	
$W(519) = 0.000194FLDISP \times VSUS - 0.08$	
$W(520) = 0.00860FLDISP - 2.49$	
$W(521) = 9.14 \times 10^{-6}VOLTOT + 0.38$	
W(522) = Input Item	
W(523) = Input Item	
W(524) = Input Item	
W(525) = Input Item	
W(526) = Input Item	
$W(527) = 0.00731FLDISP - 1.20$	Fin stabilizers
$W(527) = 0.0$	No fin stabilizers
W(528) = Input Item	

$W(550) = 3.5$

$W(551) = 0.0000417VOLTOT - 4.93$

Outfit and Furnishings--Group 6

$W(600) = 0.00230FLDISP + 3.61$

$W(601) = 0.0971NACC - 1.27$

$W(602) = 1.0$

$W(603) = 27.35FLDISP^{0.0826}$ PPTYP = 4

$W(603) = 0.0000403VOLTOT + 6.70$ PPTYP = 1,2,3,5,6,7,8

$W(604) = 0.0000321VOLTOT + 3.50$

$W(605) = 0.0000641VOLTOT + 4.26$

$W(606) = 0.0000408VOLTOT - 5.61$

$W(607) = (0.0000717VOLHUL + 10.56) \times \frac{1}{C}$

$W(608) = 0.0000712VOLTOT - 2.50$

$W(609) = 0.00113V(224) - 0.19$

$W(610) = 0.00211(V(341) + V(342) + V(343)) - 3.25$

$W(611) = 0.0152NACC + 7.37$

$W(612) = 0.000271V(210) + 3.09$

$W(613) = 0.000921(V(221) + V(313)) + 1.51$ Non flag ship

$W(613) = 0.000505(V(221) + V(313) + V(160)) + 3.54$ Flag ship

$W(614) = 0.000265V(223) + 0.58$

$W(615) = 0.404W(703)$

$W(650) = 0.00290(W(600) + \cdots W(615) + W(651)) + 0.93$

W(651) = Input Item

$C = 1.0$ Steel hull

$C = 0.55$ Aluminum hull

Armament--Group 7

W(700) = Input Item

W(703) = Input Item

W(704) = W(774) + W(784)

W(774) = Input Item

W(784) = Input Item

W(708) = Input Item

W(710) = Input Item

W(711) = Input Item

W(712) = Input Item

W(720) = 0.0

W(750) = 0.0101(W(700) + W(703) + W(704) + W(708) + W(710)

+ W(711) + W(712)) + 4.66

W(751) = 0.0173(W(700) + W(703) + W(704) + W(708) + W(710) + W(711)

+ W(712)) - 0.88

Loads

W(800) = 0.0737NACSC + 0.105NOFF + 0.073NCPO + 0.0290NCREW

+ 0.0737NFLAG + 0.0737NFLAG

W(801) = 0.0737NTRP + 0.0370NTRP

W(802) = 0.0737NPASS + 0.0290NPASS

W(803) = W(873) + W(883) + W(893)

W(873) = Input Item

W(883) = Input Item

W(893) = Input Item

W(804) = Input Item

W(805) = Input Item

W(806) = 0.0164(NACC x DUR)$^{0.8333}$

W(807) = 0.000755(NACC x DUR) + 1.81

W(808) = Input Item

$W(809)$ = Input Item

$W(810)$ = Input Item

$W(811)$ = Input Item

$W(812) = 0.0530NACC^{1.214}$

$W(813) = 0.0$	PPTYP = 5,6,7
$W(813) = 0.2022SHP^{0.530}$	PPTYP = 1,8
$W(813) = 0.000583SHP^{1.057}$	PPTYP = 2,3
$W(813) = 0.00362SHP^{0.9466}$	PPTYP = 4
$W(814) = 0.0000388SHP + 3.08$	PPTYP = 1
$W(814) = 0.00286SHP^{0.7649}$	PPTYP = 2,3
$W(814) = 5.51 \times 10^{-6}SHP^{1.387}$	PPTYP = 4
$W(814) = 0.00398SHP$	PPTYP = 7
$W(814) = 4.366SHP^{0.1122}$	PPTYP = 5,6,8

$W(815)$ = Input Item

$W(816) = 0.0$	PPTYP = 4
$W(816) = \left(\frac{ENDUR \times FRSTM}{VEND \times 2240}\right)(1.18)$	PPTYP = 1,2,3

$FRSTM = 0.5882AVEDPW + 1303.92$

$AVEDPW = 1.10SHPE$

$W(816) = WFPROP + WFELEC + WFAUXB$	PPTYP = 5,6,7,8
$WFPROP = 0.0$	PPTYP = 7
$WFPROP = \left(\frac{ENDUR \times FRCGAS}{VEND \times 2240}\right)(1.18)$	PPTYP = 8

$FRCGAS = 2589. + 0.288SHP$

$WFPROP = \left(\frac{ENDUR \times AVEDPW \times SFCAED}{VEND \times 2240}\right)(1.18)$ PPTYP = 5,6

$AVEDPW = 1.10SHPE$

$EDPWPE = \frac{AVEDPW}{NEEND}$

$NEEND = 1.0$	$AVEDPW \leq \frac{SHP}{NE}$	Single Shaft
$NEEND = 2.0$	$\frac{SHP}{NE} < AVEDPW \leq \frac{2SHP}{NE}$	Single Shaft

$$NEEND = 2.0 \qquad AVEDPW \leq \frac{2SHP}{NE} \qquad \text{Twin shafts}$$

$$NEEND = 4.0 \qquad \frac{2SHP}{NE} < AVEDPW \leq \frac{4SHP}{NE} \qquad \text{Twin shafts}$$

$$SFCAED = SFCFP(1.2298(1 - \frac{EDPWPE}{SHP/NE})^{1.6384} + 1.00)$$

$$SFCFP = -0.0000101\frac{SHP}{NE} + 0.717 \qquad PPTYP = 5$$

$$SFCFP = -0.0000101\frac{SHP}{NE} + 0.627 \qquad PPTYP = 6$$

$$WFELEC = 0.0 \qquad SSETYP = 4,5,6$$

$$WFELEC = (\frac{ENDUR \times AVEDPW \times SFCAED}{VEND \times 2240})1.05 \qquad SSETYP = 2,3$$

$$AVEDPW = \frac{KW24AV}{.8 \times .746}$$

$$AEDPWG = \frac{AVEDPW}{NGAVG}$$

$$SFCAED = SFCFP(1.2298(1 - \frac{AEDPWG}{KWPRGT/(.8 \times .746)})^{1.6384} + 1.00)$$

$$SFCFP = -0.0000101 \frac{KWPRGT}{.8 \times .746} + 0.717 \qquad SSETYP = 2$$

$$SFCFP = -0.0000101 \frac{KWPRGT}{.8 \times .746} + 0.627 \qquad SSETYP = 3$$

$$WFAUXB = \frac{ENDUR \times FRAUXB}{VEND \times 2240} 1.05$$

$$FRAUXB = 1.044 \times NACC$$

$$W(817) = 0.1432KWEMER - 5.60 \qquad PPTYP = 1,2,3,4$$

$$W(817) = WFPROP + WFELEC$$

$$WFPROP = 0.0 \qquad PPTYP = 1,2,3,4,5,6,8$$

$$WFPROP = \frac{ENDUR \times AVEDPW \times SFCAED}{VEND \times 2240} 1.18 \qquad PPTYP = 7$$

$$AVEDPW = 1.10SHPE$$

$$EDPWPE = \frac{AVEDPW}{NEEND}$$

$$NEEND = 1.0 \qquad AVEDPW \leq \frac{SHP}{NE} \qquad \text{Single Shaft}$$

$$NEEND = 2.0 \qquad \frac{SHP}{NE} < AVEDPW \leq \frac{2SHP}{NE} \qquad \text{Single Shaft}$$

$$NEEND = 2.0 \qquad AVEDPW \leq \frac{2SHP}{NE} \qquad \text{Twin Shafts}$$

$$NEEND = 4.0 \qquad \frac{2SHP}{NE} < AVEDPW \leq \frac{4SHP}{NE} \qquad \text{Twin Shafts}$$

$$RATFP = \frac{EDPWPE}{SHP/NE}$$

$$SFCAED = 0.274e^{(-5.166 \times RATFP)} + 0.359$$

$WFELEC = 0.0$ SSETYP = 1,2,3

$WFELEC = \frac{ENDUR \times FRDIEG \times NGAVG}{VEND \times 2240} 1.05$ SSETYP = 4,5,6

$$FRDIEG = 1.8845 \frac{KW24AV}{NGAVG}^{0.8273}$$

W(818) = Input Item

W(819) = Input Item

W(820) = Input Item

W(821) = Input Item

W(822) = Input Item

W(825) = Input Item

Vertical Center of Gravity

Hull Structure--Group 1

VCG(100) = 0.3661D10 + 1.45

VCG(101) = 0.1999D10 + 4.94

VCG(102) = 0.1139D10 + 0.91

VCG(103) = 1.029H - 2.59

VCG(107) = 0.8289D10 + 3.54

VCG(111) = 1.2334D10 + 4.44

VCG(112) = 0.2324H + 10.00 PPTYP = 4

VCG(112) = 0.5784H PPTYP = 5,6,8

VCG(112) = 0.9257H - 8.68 PPTYP = 1,2,3,7

VCG(113) = 0.2607H + 9.94

VCG(114) = 0.6216D10 - 2.54

VCG(115) = 0.4623D10 + 5.27

VCG(116) = Input Item

VCG(117) = Input Item

VCG(118) = 0.4529D10

VCG(119) = 0.3055D10 + 2.80

VCG(120) = 0.2436H + 1.29

VCG(121) = Input Item

VCG(122) = 0.7288D10

VCG(123) = 0.8815D10 - 0.14

VCG(125) = 0.5461D10 + 65.75

VCG(127) = Input Item

VCG(128) = Input Item

VCG(150) = 0.5829D10 + 0.68

VCG(151) = 0.348H

Propulsion--Group 2

VCG(200) = $0.000271\frac{SHP}{NSHFT} + 4.47$ PPTYP = 1,2,3,5,6,7,8

VCG(200) = $0.000322\frac{SHP}{NSHFT} + 7.58$ PPTYP = 4

VCG(201) = 0.809H + 1.09

VCG(202) = 0.5611H + 0.36

VCG(203) = 0.6603H - 5.54

VCG(204) = $0.000180\frac{SHP}{NSHFT} + 17.45$ PPTYP = 1,2,4,7

VCG(204) = 0.506D10 PPTYP = 3

VCG(204) = 1.13D10 PPTYP = 5,6,8

VCG(205) = 1.467D10 + 9.00

VCG(206) = 0.4381D10 + 6.23

VCG(207) = 0.5178D10 + 4.94

VCG(208) = 0.2643D10 + 5.24

VCG(209) = 0.2234D10 + 1.21

VCG(210) = 0.4219H + 4.12

VCG(211) = 0.3492D10 - 1.04

VCG(250) = 0.1479D10 + 11.48

VCG(251) = 0.9992H - 4.74

Electric Plant--Group 3

VCG(300) = 0.5829H + 7.40

VCG(301) = 0.4431D10 + 5.89

VCG(302) = 0.4432D10 + 10.49

VCG(303) = 0.8399D10 + 1.71

VCG(350) = 0.5471D10 - 1.63

VCG(351) = 0.3542D10 + 1.48

Communication and Control--Group 4

VCG(400) = 1.1534D10 + 12.19

VCG(401) = 0.7251D10 + 3.07

VCG(402) = Input Item

VCG(403) = 0.5068D10 + 7.04

VCG(404) = Input Item

VCG(405) = Input Item

VCG(406) = Input Item

VCG(407) = Input Item

VCG(408) = Input Item

VCG(409) = Input Item

VCG(410) = 55.0

VCG(411) = Input Item

VCG(412) = Input Item

VCG(413) = Input Item

VCG(415) = Input Item

VCG(450) = 0.2659D10 + 19.89

VCG(451) = Input Item

Auxiliary Systems--Group 5

VCG(500)	= 0.7209D10 + 3.08	Steam heat
VCG(500)	= 0.3867D10	Electric heat
VCG(501)	= 0.7663D10 + 7.14	
VCG(502)	= 0.2779D10 + 11.11	
VCG(503)	= 2.4468H - 22.62	
VCG(504)	= 0.8323D10 - 7.28	
VCG(505)	= 0.6806D10 + 4.26	
VCG(506)	= 0.8267D10 - 3.33	
VCG(507)	= 0.7804D10 + 0.95	
VCG(508)	= 0.1610D10 + 4.71	
VCG(509)	= 0.4265D10 + 8.39	
VCG(510)	= 0.2834D10 + 22.42	
VCG(511)	= 1.2224H - 6.44	
VCG(512)	= 0.3278H + 0.6557	
VCG(513)	= 16.4	
VCG(514)	= 0.8126H + 5.53	PPTYP = 1,2,3,4,7,8
VCG(514)	= 0.7735H	PPTYP = 5,6
VCG(515)	= Input Item	
VCG(516)	= 0.308D10	
VCG(517)	= 0.9938H + 1.73	
VCG(518)	= 1.8139H - 13.10	
VCG(519)	= 0.6428H + 2.40	
VCG(520)	= 0.6252D10 + 3.82	
VCG(521)	= 0.8655D10 + 8.24	
VCG(522)	= Input Item	

VCG(523) = Input Item

VCG(524) = Input Item

VCG(525) = Input Item

VCG(526) = Input Item

VCG(527) = 0.4878H

VCG(528) = Input Item

VCG(550) = 0.2804D10 + 8.53

VCG(551) = 0.5007D10 + 2.77

Outfit and Furnishings--Group 6

VCG(600) = 0.7772D10 + 11.85

VCG(601) = 1.0081D10 + 10.63

VCG(602) = 1.0183D10 + 10.99

VCG(603) = 0.3082D10 + 7.18

VCG(604) = 0.8684D10 + 3.15

VCG(605) = 0.4282D10 + 7.64

VCG(606) = 0.9046D10 - 1.03

VCG(607) = 0.5420D10 + 10.80

VCG(608) = 0.4503D10 + 7.47

VCG(609) = 0.5927D10 + 5.92

VCG(610) = 0.9440D10 - 4.55

VCG(611) = 0.8384D10 + 2.86

VCG(612) = 0.8037D10 + 1.75

VCG(613) = 1.0519D10 - 0.42

VCG(614) = 0.4172D10 + 15.28

VCG(615) = VCG(703)

VCG(650) = 1.1088D10 - 13.58

VCG(651) = Input Item

Armament--Group 7

VCG(700) = Input Item

VCG(703) = Input Item

VCG(704) = Input Item

VCG(708) = Input Item

VCG(710) = Input Item

VCG(711) = Input Item

VCG(712) = Input Item

VCG(750) = 0.546D10 + 1.44

VCG(751) = 32.7

Loads

VCG(800) = 0.7076D10 + 1.41

VCG(801) = VCG(800)

VCG(802) = VCG(800)

VCG(803) = Input Item

VCG(804) = Input Item

VCG(805) = Input Item

VCG(806) = 0.5932D10 - 2.99

VCG(807) = 0.2840D10 + 13.54

VCG(808) = Input Item

VCG(809) = Input Item

VCG(810) = Input Item

VCG(811) = Input Item

VCG(812) = 4.2

VCG(813) = 4.7

VCG(814) = 1.1519H - 2.20

VCG(815) = Input Item

VCG(816) = 0.2515H + 4.27

VCG(817) = 12.5 PPTYP = 1,2,3,4,5,6,8

VCG(817) = VCG(816) PPTYP = 7

VCG(818) = Input Item

VCG(819) = Input Item

VCG(820) = Input Item

VCG(821) = Input Item

VCG(822) = Input Item

VCG(825) = Input Item

<u>Volumes</u>

Military Mission

V(111) = Input Item

V(112) = Input Item

V(113) = Input Item

V(114) = Input Item

V(115) = Input Item

V(116) = 0.332FLDISP + 1437. + Input Item

V(121) = Input Item

V(122) = Input Item

V(123) = Input Item

V(124) = Input Item

V(125) = Input Item

V(126) = Input Item

$V(127) = 0.3577(V(121) + \cdots + V(126) + V(128))^{0.8958}$

V(128) = Input Item

V(131) = Input Item

V(132) = Input Item

V(133) = Input Item

V(134) = Input Item

V(135) = Input Item

$V(140) = 572.36NTRP^{0.8906}$

V(150) = Input Item

$V(160) = 572.36NFLAG^{0.8906}$

$V(170) = 572.36NPASS^{0.8906}$

V(180) = Input Item

Personnel

$V(211) = (777.77NOFF - 3906.56)S(2250)$

$V(212) = (526.83NOFF^{0.6533})S(2251)$

$V(213) = (128.92NOFF^{0.8878})S(2252)$

$V(214) = (255.15NCPO + 488.10)S(2253)$

$V(215) = (89.91NCPO + 584.75)S(2254)$

$V(216) = (53.78NCPO + 588.04)S(2255)$

$V(217) = (129.45NCREW + 9828.35)S(2256)$

$V(218) = (23.12NCREW + 4429.66)S(2257)$

$V(219) = (26.31NCREW + 573.84)S(2258)$

$V(221) = 3.33NACC^{1.088}S(2259)$

$V(222) = 107.22NACC^{0.7933}S(2260)$

$V(223) = (18.33NACC - 2124.47)S(2261)$

$V(224) = (16.30NACC + 1316.03)S(2262)$

$V(225) = (2.91NACC + 1473.42)S(2263)$

V(226) = Input Item

$V(231) = 0.8642(NACC \times DUR)^{0.965}S(2264)$

$V(232) = (17.22NACC - 623.12)S(2265)$

$V(233) = (7.172NACC + 793.50)S(2266)$

$V(311) = (0.00749LBP^{2.258})S(2267)$

$V(312) = 0.417FLDISP + 1062.74$

$V(313) = (0.8889FLDISP + 541.68)S(2268)$

$V(321) = 30,851 + 1.472SHP + 7.735(KWINST)$ PPTYP = 1,2,3

$V(321) = 893.21SHP^{0.4955}$ PPTYP = 7

$V(321) = 0.2685\left(SHP + \frac{KWINST}{.8 \times .746}\right)^{1.225}$ PPTYP = 4

$V(321) = 0.8346\left(SHP + \frac{KWINST}{.8 \times .746}\right)^{1.084}$ PPTYP = 5,6,8

$V(322) = 0.4547SHP^{0.9134}$ PPTYP = 1,2,3

$V(322) = 2000.0$ PPTYP = 4

$V(322) = 8.32SHP^{0.6667}$ PPTYP = 7

$V(322) = 0.00951\left(SHP + \frac{KWINST}{.8 \times .746}\right)$ PPTYP = 5,6,8

$V(323) = 0.0$ PPTYP = 5,6,7,8 1 shaft

$V(323) = 15.90LBP - 3688.67$ PPTYP = 1,2,3,4 1 shaft

$V(323) = 0.0000210LBP^{3.034}$ Any plant--2 shafts

$V(324) = 0.0183(FLDISP \times VSUS) + 2248.70$

$V(325) = (2.092FLDISP - 1516.62)S(2269)$

$V(331) = 0.6413LBP^{1.432}$

V(332) = Input Item

$V(341) = (0.8036FLDISP - 200.37)S(2270)$

$V(342) = (0.1943FLDISP + 331.42)S(2271)$

$V(343) = (0.0291FLDISP^{1.284})S(2272)$

$V(351) = 105.85W(816)^{0.8532}$ PPTYP = 1,2,3,5,6,7,8

$V(351) = 0.0$ PPTYP = 4

$V(352) = 0.5324W(813)^{1.9287}$

$V(353) = 39.0W(814)$

$V(354) = 27.93W(817)^{1.0798}$

$V(355) = 40.0W(820)$

$V(356) = 0.5353(NACC \times DUR) + 4422.87$

V(357) = Input Item

$V(361) = 40.0W(822)$

$V(362) = 0.450FLDISP - 145.90$

$V(363) = 0.0000238FLDISP^{2.314}$

V(364) = Input Item

V(365) = Input Item

$V(370) = (0.130(VOLTOT - V(370))^{0.9233})S(2773)$ Centerline passage

$V(370) = (90.90(VOLTOT - V(370))^{0.4932})S(2273)$ Port & starboard passage

V(380) = Input Item

V(390) = Input Item

APPENDIX E

PROGRAM LISTING

```
      DIMENSION INDP(3)                                                 MAIN0001
      INTEGER PPTYP,SSETYP,EMETYP                                       MAIN0002
      REAL LBP,KGTRY,LB,LENMB,LRD,MXDIS,MXVCG,LBRAT                     MAIN0003
      REAL*8 NS(100),NTYP(50),NSR(70),NCOMP(400),NWT(830),NELC(20)      MAIN0004
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)                       MAIN0005
      COMMON/CRVALS/CR1(1152),CR2(972),CR3(216)                         MAIN0006
      DATA INDP(1),INDP(2),INDP(3)/2,7,300/                             MAIN0007
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)MAIN0008
      COMMON/VOLUM/V(400),VOLTOT,VOLSST,VOLHUL,VOLMB,FNDEN(400)         MAIN0009
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP    MAIN0010
      COMMON/GENSZ/KWSSER,KWEMER,KWINST,SSETYP,EMETYP,NLSD,NMSD,NHSD,   MAIN0011
     1NGTG,NSTG,KWPRD,KWPRGT,KWPRSG,NGFCLD,NGAVG,NSSG,NEMG,KELEC        MAIN0012
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRYMAIN0013
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR     MAIN0014
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE     MAIN0015
      COMMON/MBDIM/DEPMB,LENMB,BEAMMB                                   MAIN0016
      COMMON/PEOPLE/NACC,NOFF,NCPO,NCREW,NFLAG,NTRP,NPASS,DUR,NACSC     MAIN0017
      COMMON/MISC/FINST,HULMAT,SSMAT,PASTYP                             MAIN0018
      COMMON/WTGRPS/WTGP1,WTGP2,WTGP3,WTGP4,WTGP5,WTGP6,WTGP7,VRLOAD,   MAIN0019
     1DISPLS,WTMARG,WBHS,WSS,WDHS,WARM,WFFL,WFG4,WFG5,VOLSHP,WTSHIP     MAIN0020
      COMMON/CGS/CG1,CG2,CG3,CG4,CG5,CG6,CG7,CGLDS,CGLSP,CGFLD          MAIN0021
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG              MAIN0022
      COMMON/OUT/PRTOUT,AVSP,EXCKG,ICONST,NSHIP                         MAIN0023
      COMMON/VALUES/NS,NTYP,NSR,NCOMP,NWT,NELC                          MAIN0024
C              SET THE SPECIFICATION NAMES                              MAIN0025
      DO 111 I=1,90,10                                                  MAIN0026
  111 READ 112,NS(I),NS(I+1),NS(I+2),NS(I+3),NS(I+4),NS(I+5),NS(I+6),   MAIN0027
     1NS(I+7),NS(I+8),NS(I+9)                                           MAIN0028
  112 FORMAT (10A8)                                                     MAIN0029
C              SET THE TYPE NAMES                                       MAIN0030
      DO 113 I=1,50,10                                                  MAIN0031
  113 READ 114,NTYP(I),NTYP(I+1),NTYP(I+2),NTYP(I+3),NTYP(I+4),NTYP(I+5)MAIN0032
     1,NTYP(I+6),NTYP(I+7),NTYP(I+8),NTYP(I+9)                          MAIN0033
  114 FORMAT (10A8)                                                     MAIN0034
C              SET THE SUMMARY OF RESULT NAMES                          MAIN0035
      DO 115 I=1,70,10                                                  MAIN0036
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```
  115 READ 116,NSR(I),NSR(I+1),NSR(I+2),NSR(I+3),NSR(I+4),NSR(I+5),       MAIN0037
     1NSR(I+6),NSR(I+7),NSR(I+8),NSR(I+9)                                  MAIN0038
  116 FORMAT (10A8)                                                        MAIN0039
C              SET THE FUNCTIONAL COMPONENT NAMES                          MAIN0040
      DO 117 I=100,399,10                                                  MAIN0041
  117 READ 118,NCOMP(I),NCOMP(I+1),NCOMP(I+2),NCOMP(I+3),NCOMP(I+4),       MAIN0042
     1NCOMP(I+5),NCOMP(I+6),NCOMP(I+7),NCOMP(I+8),NCOMP(I+9)               MAIN0043
  118 FORMAT (10A8)                                                        MAIN0044
C              SET THE BSCI WEIGHT GROUP NAMES                             MAIN0045
      DO 129 I=100,829,10                                                  MAIN0046
  129 READ 130,NWT(I),NWT(I+1),NWT(I+2),NWT(I+3),NWT(I+4),NWT(I+5),       MAIN0047
     1NWT(I+6),NWT(I+7),NWT(I+8),NWT(I+9)                                  MAIN0048
  130 FORMAT (10A8)                                                        MAIN0049
C              SET THE ELECTRIC GROUP NAMES                                MAIN0050
      DO 131 I=1,20,10                                                     MAIN0051
  131 READ 132,NELC(I),NELC(I+1),NELC(I+2),NELC(I+3),NELC(I+4),NELC(I+5)  MAIN0052
     1,NELC(I+6),NELC(I+7),NELC(I+8),NELC(I+9)                             MAIN0053
  132 FORMAT (10A8)                                                        MAIN0054
C                        READ IN CR ARRAY VALUES FROM TAYLOR SERIES        MAIN0055
      READ 120,CR1                                                         MAIN0056
  120 FORMAT(16F5.0)                                                       MAIN0057
      READ 121,CR2                                                         MAIN0058
  121 FORMAT(9F5.0)                                                        MAIN0059
      READ 122,CR3                                                         MAIN0060
  122 FORMAT(6F5.0)                                                        MAIN0061
C                        CALL PAYLOAD DATA ONLY ONCE                       MAIN0062
      DO 2 I=1,7                                                           MAIN0063
      DO 2 J=1,300                                                         MAIN0064
    2 P(I,J)=0.                                                            MAIN0065
      CALL DATA2(P,INDP,2100)                                              MAIN0066
      IF(INDP(1).GE.1) STOP                                                MAIN0067
C                        NUMBER THE SHIP BEING CALCULATED                  MAIN0068
      NSHIP=0                                                              MAIN0069
      DO 4 I=1,2500                                                        MAIN0070
    4 S(I)=0.                                                              MAIN0071
C                        ADDITIONAL PROBLEMS START HERE                    MAIN0072
```

```
      6 NSHIP=NSHIP+1                                                  MAIN0073
C                     CALL SPECIFICATIONS AND SPECIAL INPUT ITEMS      MAIN0074
        CALL DATA2(S,IND,2500)                                         MAIN0075
        IF(IND.GE.1) STOP                                              MAIN0076
C                     TRANSFORM PAYLOAD SPECS TO QUANTITY AND ITEM NUMBER MAIN0077
        MXITM=0                                                        MAIN0078
        DO 9 I=1,100                                                   MAIN0079
        IF(MXITM-0) 7,7,8                                              MAIN0080
      7 Q(I)=S(98+2*I)                                                 MAIN0081
        IT(I)=S(99+2*I)                                                MAIN0082
        IF(Q(I).LT.0) MXITM=I                                          MAIN0083
        GO TO 9                                                        MAIN0084
      8 Q(I)=0.                                                        MAIN0085
      9 CONTINUE                                                       MAIN0086
C                     SYMBOLIZE THE SPECIFICATIONS                     MAIN0087
        VSUS=S(1)                                                      MAIN0088
        VEND=S(2)                                                      MAIN0089
        ENDUR=S(3)                                                     MAIN0090
        LBP=S(4)                                                       MAIN0091
        LBRAT=S(5)                                                     MAIN0092
        BHRAT=S(6)                                                     MAIN0093
        CP=S(7)                                                        MAIN0094
        CX=S(8)                                                        MAIN0095
        PPTYP=S(11)                                                    MAIN0096
        SHP=S(12)                                                      MAIN0097
        NB=S(13)                                                       MAIN0098
        NR=S(14)                                                       MAIN0099
        NE=S(15)                                                       MAIN0100
        NSHFT=S(16)                                                    MAIN0101
        PRPTYP=S(17)                                                   MAIN0102
        SHFTYP=S(18)                                                   MAIN0103
        RPM=S(19)                                                      MAIN0104
        DPROP=S(20)                                                    MAIN0105
        DEPMB=S(21)                                                    MAIN0106
        LENMB=S(22)                                                    MAIN0107
        BEAMMB=S(23)                                                   MAIN0108
```

```
      PCEND=S(24)                                                       MAIN0109
      PCMXSP=S(25)                                                      MAIN0110
      DELCF=S(26)                                                       MAIN0111
      SSFTYP=S(31)                                                      MAIN0112
      EMETYP=S(32)                                                      MAIN0113
      NLSD=S(33)                                                        MAIN0114
      NMSD=S(34)                                                        MAIN0115
      NHSD=S(35)                                                        MAIN0116
      NGTG=S(36)                                                        MAIN0117
      NSTG=S(37)                                                        MAIN0118
      KWPRD=S(38)                                                       MAIN0119
      KWPRGT=S(39)                                                      MAIN0120
      KWPRSG=S(40)                                                      MAIN0121
      ELMARG=S(41)                                                      MAIN0122
      HTTYP=S(45)                                                       MAIN0123
      FINST=S(46)                                                       MAIN0124
      NOFF=S(50)                                                        MAIN0125
      NCPO=S(51)                                                        MAIN0126
      NCREW=S(52)                                                       MAIN0127
      NFLAG=S(53)                                                       MAIN0128
      NTRP=S(54)                                                        MAIN0129
      NPASS=S(55)                                                       MAIN0130
      DUR=S(56)                                                         MAIN0131
      HULMAT=S(61)                                                      MAIN0132
      SSMAT=S(62)                                                       MAIN0133
      GMBMIN=S(64)                                                      MAIN0134
      DISTOL=S(66)                                                      MAIN0135
      MXDIS=S(67)                                                       MAIN0136
      VCGTOL=S(68)                                                      MAIN0137
      MXVCG=S(69)                                                       MAIN0138
      DCMARG=S(70)                                                      MAIN0139
      FSCORR=S(71)                                                      MAIN0140
      PRTOUT=S(72)                                                      MAIN0141
      ICONST=S(73)                                                      MAIN0142
      PASTYP=S(75)                                                      MAIN0143
C               INITIALIZE ARRAYS FOR MAIN PROGRAM                      MAIN0144
```

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      DO 11 I=1,900                                                     MAIN0145
   11 W(I)=VCG(I)=VM(I)=0.                                              MAIN0146
      DO 12 I=1,400                                                     MAIN0147
   12 V(I)=VWT(I)=FNDEN(I)=0.                                           MAIN0148
      DO 13 I=1,11                                                      MAIN0149
   13 ECR(I)=EBT(I)=EAV(I)=0.                                           MAIN0150
C                         ACCOMMODATIONS                                MAIN0151
      NACSC=NOFF+NCPO+NCREW                                             MAIN0152
      NACC=NACSC+NFLAG+NTRP+NPASS                                       MAIN0153
C                         CALCULATE PAYLOAD INPUT                       MAIN0154
      CALL SPAYLD                                                       MAIN0155
C                         SET VALUE OF DELCF IF NOT SPECIFIED           MAIN0156
      IF(DELCF.EQ.0.0) DELCF=0.0004                                     MAIN0157
C                         KGEOM IS USED TO DETERMINE ROUTING FOR GEOM CALCS MAIN0158
      KGEOM=0                                                           MAIN0159
      IF(LBP.GT.0.0) KGEOM=1                                            MAIN0160
C                         DETERMINE TYPE SPEED-SHP CALC REQUIRED        MAIN0161
      JHPOPT=1                                                          MAIN0162
      IF(SHP.GT.0.0) JHPOPT=2                                           MAIN0163
C                         DETERMINE IF ELECTRIC PLANT SIZE GIVEN        MAIN0164
      KELEC=0                                                           MAIN0165
      IF(NLSD.GT.0.OR.NMSD.GT.0.OR.NHSD.GT.0.OR.NGTG.GT.0.OR.NSTG.GT.0) MAIN0166
     1KELEC=1                                                           MAIN0167
C                         ESTIMATE DISPLACEMENT AND KG AND CALC GEOMETRY MAIN0168
      NDIS=1                                                            MAIN0169
      NVCG=1                                                            MAIN0170
      EXCKG=0.                                                          MAIN0171
      NLEN=0                                                            MAIN0172
      IF(KGEOM.EQ.1) GO TO 20                                           MAIN0173
      DPTRY=7.0754*WPAYIN+914.45                                        MAIN0174
   45 CALL GEOM                                                         MAIN0175
      GO TO 37                                                          MAIN0176
   20 IF(NDIS.EQ.1) DPTRY=0.00076*LBP**2.57                             MAIN0177
   37 IF(NVCG.EQ.1) KGTRY=.1589*LBP**.7771-2.0                          MAIN0178
      CALL UWDIM                                                        MAIN0179
      IF(LBP.LT.0.) GO TO 999                                           MAIN0180
```

```
      LB=LBP/B                                                          MAIN0181
      BH=B/H                                                            MAIN0182
C                   CALC SHP GIVEN SPEED AND PROPULSIVE COEFFICIENT     MAIN0183
      IF(PCEND.EQ.0.) PCEND=.65                                         MAIN0184
      IF(PCMXSP.EQ.0.) PCMXSP=.67                                       MAIN0185
      IF(JHPOPT.EQ.2) GO TO 21                                          MAIN0186
      CALL HPCALC(VSUS,SHP,PCMXSP)                                      MAIN0187
      IF(LBP.LT.0.) GO TO 998                                           MAIN0188
      GO TO 22                                                          MAIN0189
C                   CALC MAX SUSTAINED SPEED GIVEN MAX SUSTAINED SHP    MAIN0190
   21 VMAX=8.696*(SHP/LBP)**0.2668                                      MAIN0191
   23 CALL HPCALC(VMAX,SHPS,PCMXSP)                                      MAIN0192
      IF(LBP.LT.0.) GO TO 998                                           MAIN0193
      SHP1=SHPS                                                         MAIN0194
      VMAX1=0.95*VMAX                                                   MAIN0195
      CALL HPCALC(VMAX1,SHPS,PCMXSP)                                    MAIN0196
      IF(LBP.LT.0.0) GO TO 998                                          MAIN0197
      SHP2=SHPS                                                         MAIN0198
      DELHP=(SHP1-SHP2)/(VMAX-VMAX1)                                    MAIN0199
      IF(DELHP.EQ.0.) GO TO 24                                          MAIN0200
      VMAX1=VMAX-(SHP1-SHP)/DELHP                                       MAIN0201
      IF(ABS(VMAX1-VMAX).LE.VMAX1*.005) GO TO 24                        MAIN0202
      VMAX=VMAX1                                                        MAIN0203
      GO TO 23                                                          MAIN0204
   24 VSUS=VMAX1                                                        MAIN0205
   22 SHPM=SHP/.8                                                       MAIN0206
      CALL HPCALC(VEND,SHPE,PCEND)                                      MAIN0207
      IF(LBP.LT.0.) GO TO 998                                           MAIN0208
C                   CALC ELECTRIC LOADS AND SIZE GENERATORS             MAIN0209
      CALL EPLANT                                                       MAIN0210
C                   CALC WEIGHT OF ALL LIQUIDS TO BE CARRIED            MAIN0211
      CALL MACHLQ                                                       MAIN0212
C                   CALC MINIMUM DEPTH AND BEAM OF MACHINERY BOX        MAIN0213
      CALL MBSIZE                                                       MAIN0214
C                   CALC VOLUME REQUIRED BY FUNCTIONAL GROUPING         MAIN0215
      CALL VOLUME(ERROR)                                                MAIN0216
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      IF(ERROR.GT.0.0) GO TO 888                                        MAIN0217
C                 CALC WEIGHT REQUIRED BY BSCI GROUPINGS                MAIN0218
      CALL WEIGHT                                                       MAIN0219
      IF(ABS(DISPFL-DPTRY).LT.DISTOL) GO TO 38                          MAIN0220
      IF(NDIS.GE.2) GO TO 39                                            MAIN0221
      NHALF=1                                                           MAIN0222
      FACTOR=0.60                                                       MAIN0223
      GO TO 63                                                          MAIN0224
   39 FACTOR=(DPTRY-DISPFL-DP1+WT1)/(DPTRY-DP1)                         MAIN0225
   63 DP1=DPTRY                                                         MAIN0226
      WT1=DISPFL                                                        MAIN0227
      DPTRY=DPTRY-(DPTRY-DISPFL)/FACTOR                                 MAIN0228
      IF (FACTOR.GE.0.) GO TO 10                                        MAIN0229
      IF(DPTRY.LT.0.) GO TO 60                                          MAIN0230
      DPTRY=(.5**NHALF)*DP1                                             MAIN0231
      GO TO 65                                                          MAIN0232
   60 DPTRY=(2.**NHALF)*DP1                                             MAIN0233
   65 NHALF=NHALF+1                                                     MAIN0234
   10 IF(NDIS.GT.MXDIS) GO TO 995                                       MAIN0235
      NDIS=NDIS+1                                                       MAIN0236
      IF(NLEN.GT.0) KGEOM=1                                             MAIN0237
      IF(KGEOM.EQ.0) GO TO 45                                           MAIN0238
      GO TO 37                                                          MAIN0239
   38 CONTINUE                                                          MAIN0240
      NDIS=1                                                            MAIN0241
      CALL VRTCG                                                        MAIN0242
      IF(ABS(CGFLD-KGTRY).LT.VCGTOL) GO TO 41                           MAIN0243
      IF(NVCG.GT.MXVCG) GO TO 994                                       MAIN0244
      IF(CGFLD.LT.KGTRY) GO TO 42                                       MAIN0245
   43 KGTRY=(CGFLD+KGTRY)/2.                                            MAIN0246
      NVCG=NVCG+1                                                       MAIN0247
      IF(NLEN.GT.0) KGEOM=1                                             MAIN0248
      IF(KGEOM.EQ.0) GO TO 45                                           MAIN0249
      GO TO 37                                                          MAIN0250
   42 IF(R.LT..001) GO TO 43                                            MAIN0251
      EXCKG=KGTRY-CGFLD                                                 MAIN0252
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   41 CONTINUE                                                         MAIN0253
      NVCG=1                                                           MAIN0254
      IF(LRD.LE.LBP) GO TO 40                                          MAIN0255
  888 IF(NLEN.GT.0) GO TO 499                                          MAIN0256
      PRINT 500,NSHIP                                                  MAIN0257
      GO TO 498                                                        MAIN0258
  499 PRINT 501,NSHIP                                                  MAIN0259
  501 FORMAT(1H0,10X,'SHIP NUMBER',I4)                                 MAIN0260
  498 PRINT 491,LBP,LRD                                                MAIN0261
  491 FORMAT(1H0,10X,'LBP=',F6.1,3X,'LRD=',F6.1)                       MAIN0262
      PRINT 103                                                        MAIN0263
  103 FORMAT(1H0,'TOO LARGE A VOLUME REQUIRED FOR SOLUTION USING INPUT L MAIN0264
     1ENGTH, LENGTH BEING INCREASED')                                  MAIN0265
      NLEN=NLEN+1                                                      MAIN0266
      LBP=LBP+10.0                                                     MAIN0267
      IF(NLEN.GT.10) GO TO 996                                         MAIN0268
      GO TO 20                                                         MAIN0269
   40 CALL FNCGRP                                                      MAIN0270
      CALL SEASPD(AVSP)                                                MAIN0271
      CALL OUTPUT                                                      MAIN0272
      GO TO 6                                                          MAIN0273
  994 PRINT 500,NSHIP                                                  MAIN0274
  500 FORMAT(1H1,10X,'SHIP NUMBER',I4)                                 MAIN0275
      PRINT 106,VCGTOL,MXVCG                                           MAIN0276
  106 FORMAT(1H0,'NO BALANCE BETWEEN ASSUMED AND CALC KG WITHIN',F5.2,  MAIN0277
     1' FEET COULD BE MADE IN',F4.0,' ITERATIONS')                     MAIN0278
      GO TO 1000                                                       MAIN0279
  995 PRINT 500,NSHIP                                                  MAIN0280
      PRINT 105,DISTOL,MXDIS                                           MAIN0281
  105 FORMAT(1H0,'NO BALANCE BETWEEN WEIGHT AND DISPLACEMENT WITHIN',   MAIN0282
     1F5.2,' TONS COULD BE MADE IN',F4.0,' ITERATIONS')                MAIN0283
      GO TO 1000                                                       MAIN0284
  996 PRINT 500,NSHIP                                                  MAIN0285
      PRINT 104                                                        MAIN0286
  104 FORMAT(1H0,'TOO LARGE A VOLUME REQUIRED FOR SOLUTION USING INPUT L MAIN0287
     1ENGTH, TRY A LONGER SHIP')                                       MAIN0288
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      GO TO 1000
  998 PRINT 500,NSHIP
      PRINT 101
  101 FORMAT(1H0,'LIMITS OF STORED RESISTANCE DATA EXCEEDED')
      GO TO 1000
  999 PRINT 500,NSHIP
      PRINT 100
  100 FORMAT(1H0,'VCG IS ABOVE LIMITS OF STORED DATA')
 1000 PRINT 102
  102 FORMAT(1H0,'PROGRAM PROCEEDING TO NEXT INPUT CASE')
      GO TO 6
      END
```

```
      SUBROUTINE DATA2 (X,IND,K)                                        DAT20001
      DIMENSION IND(3),COL(72),ICOL(72),X(K)                            DAT20002
      EQUIVALENCE (COL,ICOL),(BLANK,IBLANK),(ANINE,NINE),(COMMA,KOMMA), DAT20003
     X(PERIOD,IPRIOD),(PLUS,IPLUS),(AMINUS,MINUS),(TEMP,ITEMP),         DAT20004
     X(SHIFT,ISHIFT)                                                    DAT20005
      IN=2                                                              DAT20006
      IOUT=3                                                            DAT20007
      IBLANK=1077952576                                                 DAT20008
      KOMMA=1799372864                                                  DAT20009
      IPRIOD=1262501952                                                 DAT20010
      IPLUS=1312833600                                                  DAT20011
      MINUS=1614823488                                                  DAT20012
      READ 10, (COL(I), I=1,72)                                         DAT20013
   10 FORMAT (72A1)                                                     DAT20014
      DO 20 I=1,72                                                      DAT20015
      IF(COL(I).NE.BLANK) GO TO 50                                      DAT20016
   20 CONTINUE                                                          DAT20017
      IND(1)=1                                                          DAT20018
      RETURN                                                            DAT20019
   30 READ 10, (COL(I), I=1,72)                                         DAT20020
      DO 40 I=1,72                                                      DAT20021
      IF (COL(I).NE.BLANK) GO TO 50                                     DAT20022
   40 CONTINUE                                                          DAT20023
      IND(1)=0                                                          DAT20024
      RETURN                                                            DAT20025
   50 SWCH=0.                                                           DAT20026
      IDIM=0                                                            DAT20027
      ISUB=0                                                            DAT20028
      I=0                                                               DAT20029
      KNT=1                                                             DAT20030
      IPROD=1                                                           DAT20031
   60 I=I+1                                                             DAT20032
   70 IF(ICOL(I).EQ.IBLANK) GO TO 60                                    DAT20033
   75 IF(ICOL(I)+0) 110,110,90                                          DAT20034
   90 IND(1)=2                                                          DAT20035
      PRINT 100, (COL(I),I=1,72)                                        DAT20036
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100 FORMAT (16X, 16H21D DATA CARD..., 72A1)                         DAT20037
    RETURN                                                          DAT20038
110 IF(ICOL(I).EQ.-264224704) ITEMP=0                               DAT20039
    IF(ICOL(I).EQ.-247447488) ITEMP=1                               DAT20040
    IF(ICOL(I).EQ.-230670272) ITEMP=2                               DAT20041
    IF(ICOL(I).EQ.-213893056) ITEMP=3                               DAT20042
    IF(ICOL(I).EQ.-197115840) ITEMP=4                               DAT20043
    IF(ICOL(I).EQ.-180338624) ITEMP=5                               DAT20044
    IF(ICOL(I).EQ.-163561408) ITEMP=6                               DAT20045
    IF(ICOL(I).EQ.-146784192) ITEMP=7                               DAT20046
    IF(ICOL(I).EQ.-130006976) ITEMP=8                               DAT20047
    IF(ICOL(I).EQ.-113229760) ITEMP=9                               DAT20048
    IF(ICOL(I).LT.-264224704) GO TO 90                              DAT20049
    IDIM=10*IDIM+ITEMP                                              DAT20050
120 I=I+1                                                           DAT20051
    IF (I-72) 130,130,90                                            DAT20052
130 IF(ICOL(I).EQ.IBLANK) GO TO 190                                 DAT20053
140 IF(ICOL(I).NE.KOMMA) GO TO 75                                   DAT20054
150 KNT=KNT+1                                                       DAT20055
    IF(KNT-IND(1)) 160,160,90                                       DAT20056
160 IF (KNT-2) 170,170,180                                          DAT20057
170 ISUB=IDIM                                                       DAT20058
    IDIM=0                                                          DAT20059
    IPROD=IPROD*IND(KNT)                                            DAT20060
    GO TO 120                                                       DAT20061
180 ISUB=ISUB+(IDIM-1)*IPROD                                        DAT20062
    IPROD=IPROD*IND(KNT)                                            DAT20063
    IDIM=0                                                          DAT20064
    GO TO 120                                                       DAT20065
190 IF (KNT-1) 195,195,200                                          DAT20066
195 ISUB=IDIM                                                       DAT20067
    GO TO 210                                                       DAT20068
200 IF(KNT-IND(1)) 90,205,90                                        DAT20069
205 ISUB=ISUB+(IDIM-1)*IPROD                                        DAT20070
210 I=I+1                                                           DAT20071
    IF (I-72) 230,230,220                                           DAT20072
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```
220 IF(SWCH-0.) 90,90,30                                DAT20073
230 IF(ICOL(I).EQ.IBLANK) GO TO 210                     DAT20074
240 VAL=0.                                              DAT20075
    SIN=0.                                              DAT20076
    PER=0.                                              DAT20077
    EXPON=0.                                            DAT20078
    SINE=0.                                             DAT20079
    PERE=0.                                             DAT20080
250 IF(ICOL(I)+0) 370,370,260                           DAT20081
260 IF(ICOL(I).EQ.IPRIOD) GO TO 350                     DAT20082
270 IF(ICOL(I).EQ.IPLUS) GO TO 320                      DAT20083
280 IF(ICOL(I).NE.MINUS) GO TO 90                       DAT20084
290 IF(VAL-0.) 420,300,420                              DAT20085
300 IF(SIN-0.) 90,310,90                                DAT20086
310 SIN=-1.                                             DAT20087
    GO TO 410                                           DAT20088
320 IF (VAL-0.) 440,330,440                             DAT20089
330 IF(SIN-0.) 90,340,90                                DAT20090
340 SIN=1.                                              DAT20091
    GO TO 410                                           DAT20092
350 IF(PER-0.) 90,360,90                                DAT20093
360 PER=1.                                              DAT20094
    AMAG=10.                                            DAT20095
    GO TO 410                                           DAT20096
370 IF(ICOL(I).EQ.-264224704) ITEMP=0                   DAT20097
    IF(ICOL(I).EQ.-247447488) ITEMP=1                   DAT20098
    IF(ICOL(I).EQ.-230670272) ITEMP=2                   DAT20099
    IF(ICOL(I).EQ.-213893056) ITEMP=3                   DAT20100
    IF(ICOL(I).EQ.-197115840) ITEMP=4                   DAT20101
    IF(ICOL(I).EQ.-180338624) ITEMP=5                   DAT20102
    IF(ICOL(I).EQ.-163561408) ITEMP=6                   DAT20103
    IF(ICOL(I).EQ.-146784192) ITEMP=7                   DAT20104
    IF(ICOL(I).EQ.-130006976) ITEMP=8                   DAT20105
    IF(ICOL(I).EQ.-113229760) ITEMP=9                   DAT20106
    IF(ICOL(I).LT.-264224704) GO TO 90                  DAT20107
    TEMP=ITEMP                                          DAT20108
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380 IF(PER-0.) 390,390,400                                        DAT20109
390 VAL=10.*VAL+TEMP                                              DAT20110
    GO TO 410                                                     DAT20111
400 VAL=VAL+(TEMP/AMAG)                                           DAT20112
    AMAG=10.*AMAG                                                 DAT20113
410 I=I+1                                                         DAT20114
    IF (I-72) 415,415,550                                         DAT20115
415 IF(ICOL(I).EQ.IBLANK) GO TO 550                               DAT20116
    IF(ICOL(I).NE.IBLANK) GO TO 250                               DAT20117
420 IF(SINE-0.) 90,430,90                                         DAT20118
430 SINE=-1.                                                      DAT20119
    GO TO 530                                                     DAT20120
440 IF(SINE-0.) 90,450,90                                         DAT20121
450 SINE=1.                                                       DAT20122
    GO TO 530                                                     DAT20123
460 IF(ICOL(I)+0) 500,500,470                                     DAT20124
470 IF(ICOL(I).NE.IPRIOD) GO TO 90                                DAT20125
480 IF(PERE-0.) 90,490,90                                         DAT20126
490 PERE=1.                                                       DAT20127
    AMAG=10.                                                      DAT20128
    GO TO 530                                                     DAT20129
500 IF(ICOL(I).EQ.-264224704) ITEMP=0                             DAT20130
    IF(ICOL(I).EQ.-247447488) ITEMP=1                             DAT20131
    IF(ICOL(I).EQ.-230670272) ITEMP=2                             DAT20132
    IF(ICOL(I).EQ.-213893056) ITEMP=3                             DAT20133
    IF(ICOL(I).EQ.-197115840) ITEMP=4                             DAT20134
    IF(ICOL(I).EQ.-180338624) ITEMP=5                             DAT20135
    IF(ICOL(I).EQ.-163561408) ITEMP=6                             DAT20136
    IF(ICOL(I).EQ.-146784192) ITEMP=7                             DAT20137
    IF(ICOL(I).EQ.-130006976) ITEMP=8                             DAT20138
    IF(ICOL(I).EQ.-113229760) ITEMP=9                             DAT20139
    IF(ICOL(I).LT.-264224704) GO TO 90                            DAT20140
    TEMP=ITEMP                                                    DAT20141
    IF(PERE-0.) 510,510,520                                       DAT20142
510 EXPON=10.*EXPON+TEMP                                          DAT20143
    GO TO 530                                                     DAT20144
```

```
520 EXPON=EXPON+(TEMP/AMAG)                                          DAT20145
    AMAG=10.*AMAG                                                    DAT20146
530 I=I+1                                                            DAT20147
    IF (I-72) 540,540,550                                            DAT20148
540 IF(ICOL(I).NE.IBLANK) GO TO 460                                  DAT20149
550 IF(SIN-0.) 570,560,570                                           DAT20150
560 SIN=1.                                                           DAT20151
570 X(ISUB)=SIN*VAL*10.**(SINE*EXPON)                                DAT20152
    ISUB=ISUB+1                                                      DAT20153
    SWCH=1.                                                          DAT20154
    GO TO 210                                                        DAT20155
    END                                                              DAT20156
```

```
      SUBROUTINE SPAYLD
      DIMENSION WW(900)
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)
C                     CALCULATE WEIGHT OF PAYLOAD ITEMS
      DO 129 J=1,900
  129 WW(J)=0.
      DO 130 I=1,100
      IF(Q(I).LT.0.) GO TO 133
      IF(IT(I).EQ.0) GO TO 130
      IF(P(1,IT(I)).EQ.0.) GO TO 130
      WW(P(1,IT(I)))=Q(I)*P(3,IT(I))
      W(P(1,IT(I)))=W(P(1,IT(I)))+WW(P(1,IT(I)))
  130 CONTINUE
C                     CALCULATE WEIGHT OF SPECIAL PAYLOAD ITEMS
  133 DO 131 K=2300,2499,10
      IF(S(K).EQ.0.) GO TO 131
      WW(S(K))=S(K+2)
      W(S(K))=W(S(K))+WW(S(K))
  131 CONTINUE
      WPAYIN=0.0
C                     SUM PAYLOAD WEIGHT INPUT
      DO 132 M=1,900
  132 WPAYIN=WPAYIN+W(M)
      RETURN
      END
```

```
      SUBROUTINE GEOM                                                   GEOM0001
      REAL LBP,LBRAT                                                    GEOM0002
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY GEOM0003
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG              GEOM0004
      DPTRY=DPTRY/1.014                                                 GEOM0005
      CB=CP*CX                                                          GEOM0006
      CV=CB/(BHRAT*LBRAT**2.)                                           GEOM0007
      LBP=(35.*DPTRY/CV)**(1./3.)                                       GEOM0008
      B=LBP/LBRAT                                                       GEOM0009
      H=B/BHRAT                                                         GEOM0010
      DPTRY=DPTRY*1.014                                                 GEOM0011
      RETURN                                                            GEOM0012
      END                                                               GEOM0013
```

```
      SUBROUTINE UWDIM                                                  UWDI0001
      REAL LBP                                                          UWDI0002
      COMMON/UND/FSCORR,CP,CX,C5,C4,B1,CWP,LBP,R,LBRAT,BHRAT,DPTRY      UWDI0003
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG              UWDI0004
      DIMENSION A(5),B(5),C(5)                                          UWDI0005
      DPTRY=DPTRY/1.014                                                 UWDI0006
      CB=CP*CX                                                          UWDI0007
      CWP=0.425*CB+0.526                                                UWDI0008
      CALPH=.0733*CP+0.0026                                             UWDI0009
      C1=DPTRY*35./(LBP*CP*CX)                                          UWDI0010
      C2=0.833-CP*CX/(3.*CWP)                                           UWDI0011
      C3=LBP*CALPH/(DPTRY*35.)                                          UWDI0012
      C4=C4+FSCORR                                                      UWDI0013
C     R=KB+BM-KG-FSCORR-GM=C2*H+C3*B**3-C4-C5*B                         UWDI0014
C     H=C1/B                                                            UWDI0015
C     DR/DB=-C1*C2/B**2+3*C3*B**2-C5=0 FOR MINIMUM POINT                UWDI0016
      BMIN=SQRT((C5+SQRT(C5**2+12.*C1*C2*C3))/(6.*C3))                  UWDI0017
      HMIN=C1/BMIN                                                      UWDI0018
      BTR=BMIN/HMIN                                                     UWDI0019
      IF(BTR.LT.2..OR.BTR.GT.4.) GO TO 1                                UWDI0020
      R=C2*HMIN+C3*BMIN**3-C4-C5*BMIN                                   UWDI0021
      IF(R.LE.0.0) GO TO 2                                              UWDI0022
      C4=C4-FSCORR+R                                                    UWDI0023
      B1=BMIN                                                           UWDI0024
      H=HMIN                                                            UWDI0025
      DPTRY=DPTRY*1.014                                                 UWDI0026
      RETURN                                                            UWDI0027
    1 HMAX=SQRT(C1/2.005)                                               UWDI0028
      BMIN=C1/HMAX                                                      UWDI0029
      R=C2*HMAX+C3*BMIN**3-C4-C5*BMIN                                   UWDI0030
      IF(R.LE.0.0) GO TO 2                                              UWDI0031
      C4=C4-FSCORR+R                                                    UWDI0032
      B1=BMIN                                                           UWDI0033
      H=HMAX                                                            UWDI0034
      DPTRY=DPTRY*1.014                                                 UWDI0035
      RETURN                                                            UWDI0036
```

```
    2 HMIN=SQRT(C1/3.995)                                         UWDI0037
      BMAX=C1/HMIN                                                UWDI0038
      R=C2*HMIN+C3*BMAX**3-C4-C5*BMAX                             UWDI0039
      IF(R.LT.0.0) GO TO 6                                        UWDI0040
      A(1)=1.0                                                    UWDI0041
      A(2)=-C4/C2                                                 UWDI0042
      A(3)=-C1*C5/C2                                              UWDI0043
      A(4)=0.0                                                    UWDI0044
      A(5)=C3/C2*C1**3                                            UWDI0045
      B(1)=1.0                                                    UWDI0046
      C(1)=1.0                                                    UWDI0047
      Z=HMIN                                                      UWDI0048
C     H**4-C4/C2*H**3-C1/C2*C5*H**2-C1**3*C3/C2=0                 UWDI0049
    3 DO 4 I=2,5                                                  UWDI0050
      B(I)=A(I)+Z*B(I-1)                                          UWDI0051
    4 C(I)=B(I)+Z*C(I-1)                                          UWDI0052
      ZNEW=Z-B(5)/C(4)                                            UWDI0053
      IF(ABS(ZNEW-Z).LE.0.01*ZNEW) GO TO 5                        UWDI0054
      Z=ZNEW                                                      UWDI0055
      GO TO 3                                                     UWDI0056
    5 H=ZNEW                                                      UWDI0057
      B1=C1/H                                                     UWDI0058
      C4=C4-FSCORR                                                UWDI0059
      R=0.                                                        UWDI0060
      DPTRY=DPTRY*1.014                                           UWDI0061
      RETURN                                                      UWDI0062
    6 LBP=-1000.0                                                 UWDI0063
      DPTRY=DPTRY*1.014                                           UWDI0064
      RETURN                                                      UWDI0065
      END                                                         UWDI0066
```

```
      SUBROUTINE HPCALC(VK,SHPS,PC)                                     HPCL0001
      REAL LBP,KGTRY                                                    HPCL0002
      INTEGER PPTYP                                                     HPCL0003
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR     HPCL0004
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY HPCL0005
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG              HPCL0006
      DISPL=DPTRY/1.014                                                 HPCL0007
      VOL=DISPL*35.                                                     HPCL0008
      BDR=B/H                                                           HPCL0009
      RN=VK*LBP*132050.                                                 HPCL0010
      CF=.075/(ALOG10(RN)-2.)**2+DELCF                                  HPCL0011
      SLRAT=VK/(SQRT(LBP))                                              HPCL0012
      CV=VOL/(LBP)**3                                                   HPCL0013
      IF(BDR.LT.2..OR.BDR.GT.4.) GO TO 1000                             HPCL0014
      IF(CP.LT..48.OR.CP.GT..7) GO TO 1000                              HPCL0015
      IF(SLRAT.LT..5.OR.SLRAT.GT.2.) GO TO 1000                         HPCL0016
      IF(CV.LT..001.OR.CV.GT..006) GO TO 1000                           HPCL0017
      IF(CV.GT..003.AND.SLRAT.GT.1.3) GO TO 1000                        HPCL0018
      CALL CRVAL(BDR,CV,CP,SLRAT,CR)                                    HPCL0019
      CT=CF+CR*.001                                                     HPCL0020
      S=(1.7*LBP*H+VOL/H)*(.0053*BDR*BDR-.02*BDR+3.*CV+.08*CP+.926)     HPCL0021
      A=.00438*1.9905*S                                                 HPCL0022
      EHPBH=A*VK**3*CT                                                  HPCL0023
      IF(SLRAT.LE.0.85) EHPAPP=1.3*EHPBH                                HPCL0024
      IF(SLRAT.LE.1.6.AND.SLRAT.GT.0.85) EHPAPP=(1.4587-0.1867*SLRAT)   HPCL0025
     1*EHPBH                                                            HPCL0026
      IF(SLRAT.LE.1.92.AND.SLRAT.GT.1.6) EHPAPP=(1.310-0.0938*SLRAT)    HPCL0027
     1*EHPBH                                                            HPCL0028
      IF(SLRAT.GT.1.92) EHPAPP=1.13*EHPBH                               HPCL0029
      IF(SLRAT.LE.0.70) EHP=1.1*EHPAPP                                  HPCL0030
      IF(SLRAT.LE.0.82.AND.SLRAT.GT.0.70) EHP=(1.205-0.150*SLRAT)*EHPAPP HPCL0031
      IF(SLRAT.LE.1.18.AND.SLRAT.GT.0.82) EHP=(1.3827-0.3667*SLRAT)     HPCL0032
     1*EHPAPP                                                           HPCL0033
      IF(SLRAT.LE.1.4.AND.SLRAT.GT.1.18) EHP=(1.1109-0.1364*SLRAT)      HPCL0034
     1*EHPAPP                                                           HPCL0035
      IF(SLRAT.LE.1.78.AND.SLRAT.GT.1.4) EHP=(0.9753-0.0395*SLRAT)      HPCL0036
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```
     1*EHPAPP                                                           HPCL0037
      IF(SLRAT.GT.1.78)  EHP=(0.8645+0.0227*SLRAT)*EHPAPP               HPCL0038
      SHPS=EHP/PC                                                       HPCL0039
      RETURN                                                            HPCL0040
 1000 LBP=-1000.                                                        HPCL0041
      RETURN                                                            HPCL0042
      END                                                               HPCL0043
```

```
      SUBROUTINE CRVAL(BTR,CV,CP,VL,CR)                                 CRVL0001
      COMMON/CRVALS/CR1(1152),CR2(972),CR3(216)                         CRVL0002
      I1(J,K,L,M)=(K-1)*384+(J-1)*192+(L-1)*16+M                        CRVL0003
      I2(J,K,L,M)=(K-1)*324+(J-3)*108+(L-1)*9+M                         CRVL0004
      I3(J,K,L,M)=(K-1)*72+(L-1)*6+M                                    CRVL0005
      IF(BTR.GE.3.) K1=2                                                CRVL0006
      IF(BTR.LT.3.) K1=1                                                CRVL0007
      K2=K1+1                                                           CRVL0008
      CP1=.68                                                           CRVL0009
    3 IF(CP-CP1+.0001) 1,2,2                                            CRVL0010
    1 CP1=CP1-.02                                                       CRVL0011
      GO TO 3                                                           CRVL0012
    2 L1=IFIX((CP1-.46)*50.1)                                           CRVL0013
      L2=L1+1                                                           CRVL0014
      CV1=.005                                                          CRVL0015
    4 IF(CV-CV1+.00001) 5,6,6                                           CRVL0016
    5 CV1=CV1-.001                                                      CRVL0017
      GO TO 4                                                           CRVL0018
   13 J1=J1-1                                                           CRVL0019
      CV1=CV1-.001                                                      CRVL0020
      GO TO 14                                                          CRVL0021
    6 J1=IFIX(CV1*1001.)                                                CRVL0022
      IF(J1.EQ.5.AND.VL.GT.1.) GO TO 13                                 CRVL0023
      IF(J1.EQ.2.AND.VL.GT.1.3) GO TO 13                                CRVL0024
   14 J2=J1+1                                                           CRVL0025
      VL1=1.9                                                           CRVL0026
    7 IF(VL-VL1+.0001) 8,9,9                                            CRVL0027
    8 VL1=VL1-.1                                                        CRVL0028
      GO TO 7                                                           CRVL0029
    9 M1=IFIX((VL1-.4)*10.1)                                            CRVL0030
      M2=M1+1                                                           CRVL0031
      J=J1                                                              CRVL0032
      INDEX=1                                                           CRVL0033
   11 IF(J.GE.3) GO TO 10                                               CRVL0034
      I=I1(J,K1,L1,M1)                                                  CRVL0035
      CRA=CR1(I)                                                        CRVL0036
```

```
      I=I1(J,K1,L1,M2)                                                  CRVL0037
      CRB=CR1(I)                                                        CRVL0038
      I=I1(J,K1,L2,M1)                                                  CRVL0039
      CRC=CR1(I)                                                        CRVL0040
      I=I1(J,K1,L2,M2)                                                  CRVL0041
      CRD=CR1(I)                                                        CRVL0042
      I=I1(J,K2,L1,M1)                                                  CRVL0043
      CRE=CR1(I)                                                        CRVL0044
      I=I1(J,K2,L1,M2)                                                  CRVL0045
      CRF=CR1(I)                                                        CRVL0046
      I=I1(J,K2,L2,M1)                                                  CRVL0047
      CRG=CR1(I)                                                        CRVL0048
      I=I1(J,K2,L2,M2)                                                  CRVL0049
      CRH=CR1(I)                                                        CRVL0050
      GO TO 50                                                          CRVL0051
   10 IF(J.EQ.6) GO TO 12                                               CRVL0052
      I=I2(J,K1,L1,M1)                                                  CRVL0053
      CRA=CR2(I)                                                        CRVL0054
      I=I2(J,K1,L1,M2)                                                  CRVL0055
      CRB=CR2(I)                                                        CRVL0056
      I=I2(J,K1,L2,M1)                                                  CRVL0057
      CRC=CR2(I)                                                        CRVL0058
      I=I2(J,K1,L2,M2)                                                  CRVL0059
      CRD=CR2(I)                                                        CRVL0060
      I=I2(J,K2,L1,M1)                                                  CRVL0061
      CRE=CR2(I)                                                        CRVL0062
      I=I2(J,K2,L1,M2)                                                  CRVL0063
      CRF=CR2(I)                                                        CRVL0064
      I=I2(J,K2,L2,M1)                                                  CRVL0065
      CRG=CR2(I)                                                        CRVL0066
      I=I2(J,K2,L2,M2)                                                  CRVL0067
      CRH=CR2(I)                                                        CRVL0068
      GO TO 50                                                          CRVL0069
   12 I=I3(J,K1,L1,M1)                                                  CRVL0070
      CRA=CR3(I)                                                        CRVL0071
      I=I3(J,K1,L1,M2)                                                  CRVL0072
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```
      CRB=CR3(I)                                              CRVL0073
      I=I3(J,K1,L2,M1)                                        CRVL0074
      CRC=CR3(I)                                              CRVL0075
      I=I3(J,K1,L2,M2)                                        CRVL0076
      CRD=CR3(I)                                              CRVL0077
      I=I3(J,K2,L1,M1)                                        CRVL0078
      CRE=CR3(I)                                              CRVL0079
      I=I3(J,K2,L1,M2)                                        CRVL0080
      CRF=CR3(I)                                              CRVL0081
      I=I3(J,K2,L2,M1)                                        CRVL0082
      CRG=CR3(I)                                              CRVL0083
      I=I3(J,K2,L2,M2)                                        CRVL0084
      CRH=CR3(I)                                              CRVL0085
   50 V=(VL-VL1)*10.                                          CRVL0086
      C=(CP-CP1)*50.                                          CRVL0087
      BTR1=FLOAT((K1-1))*.75+2.25                             CRVL0088
      B=(BTR-BTR1)/.75                                        CRVL0089
      C1=(CRB-CRA)*V+CRA                                      CRVL0090
      C2=(CRD-CRC)*V+CRC                                      CRVL0091
      C3=(CRF-CRE)*V+CRE                                      CRVL0092
      C4=(CRH-CRG)*V+CRG                                      CRVL0093
      C5=(C2-C1)*C+C1                                         CRVL0094
      C6=(C4-C3)*C+C3                                         CRVL0095
      C7=(C6-C5)*B+C5                                         CRVL0096
      IF(INDEX.GE.2) GO TO 51                                 CRVL0097
      A=C7                                                    CRVL0098
      J=J2                                                    CRVL0099
      INDEX=2                                                 CRVL0100
      GO TO 11                                                CRVL0101
   51 D=C7                                                    CRVL0102
      CR=(D-A)*(CV-CV1)*1000.+A                               CRVL0103
      RETURN                                                  CRVL0104
      END                                                     CRVL0105
```

```
      SUBROUTINE EPLANT
      REAL LBP,LBRAT
      INTEGER PPTYP,SSETYP,EMETYP
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP
      COMMON/GENSZ/KWSSER,KWEMER,KWINST,SSETYP,EMETYP,NLSD,NMSD,NHSD,
     1NGTG,NSTG,KWPRD,KWPRGT,KWPRSG,NGFCLD,NGAVG,NSSG,NEMG,KELEC
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR
      FLDISP=DPTRY
      A=1.0
      IF(PPTYP.EQ.4) A=4.0
      E=1.0
      IF(PPTYP.EQ.4) E=2.0
C                     CALC CRUISE KW LOADS
      ECR(1)=(0.00173*(FLDISP*VSUS)-64.62)*A
      ECR(2)=(0.0517*FLDISP+19.27)*E
      ECR(3)=2.0
      ECR(4)=6.9
      WGP4=0.0
C                     CALC WTGP 4 MINUS WTGP 451
      DO 2 I=400,499
    2 WGP4=WGP4+W(I)
      WGP4=WGP4-W(451)-W(486)-W(496)
      ECR(5)=0.2041*WGP4+172.71
      ECR(6)=25.6
      ECR(7)=0.0169*FLDISP+59.38
      ECR(8)=0.1649*FLDISP-344.33
      IF(HTTYP.EQ.2.0) ECR(8)=0.1320*FLDISP+438.96
      ECR(9)=110.0
      ECR(10)=ELMARG*(ECR(1)+ECR(2)+ECR(3)+ECR(4)+ECR(5)+ECR(6)+ECR(7)+
     1ECR(8)+ECR(9))
      DO 900 K=2200,2209
      IF(S(K).EQ.0.0) GO TO 900
```

```
      ECR(K-2199)=S(K)                                                  EPLT0037
  900 CONTINUE                                                          EPLT0038
      ECR(11)=0.0                                                       EPLT0039
      DO 4 I=1,10                                                       EPLT0040
    4 ECR(11)=ECR(11)+ECR(I)                                            EPLT0041
      IF(S(2210).GT.0.0) ECR(11)=S(2210)                                EPLT0042
C                     CALC BATTLE KW LOADS                              EPLT0043
      EBT(1)=(0.00209*(FLDISP*VSUS)-99.19)*A                            EPLT0044
      EBT(2)=(0.0746*FLDISP-14.21)*E                                    EPLT0045
      EBT(3)=1.5                                                        EPLT0046
      EBT(4)=1.2                                                        EPLT0047
      EBT(5)=0.3613*WGP4+174.52                                         EPLT0048
C                     CALC WTGP 7                                       EPLT0049
      WTGP7=0.0                                                         EPLT0050
      DO 6 J=700,799                                                    EPLT0051
    6 WTGP7=WTGP7+W(J)                                                  EPLT0052
      WTGP7=WTGP7-W(774)-W(784)-W(794)                                  EPLT0053
      EBT(6)=1.670*WTGP7-63.79                                          EPLT0054
      EBT(7)=0.00794*FLDISP+64.70                                       EPLT0055
      EBT(8)=0.0382*FLDISP+193.40                                       EPLT0056
      EBT(9)=214.6                                                      EPLT0057
      EBT(10)=ELMARG*(EBT(1)+EBT(2)+EBT(3)+EBT(4)+EBT(5)+EBT(6)+EBT(7)+ EPLT0058
     1EBT(8)+EBT(9))                                                    EPLT0059
      DO 901 M=2211,2220                                                EPLT0060
      IF(S(M).EQ.0.0) GO TO 901                                         EPLT0061
      EBT(M-2210)=S(M)                                                  EPLT0062
  901 CONTINUE                                                          EPLT0063
      EBT(11)=0.0                                                       EPLT0064
      DO 8 I=1,10                                                       EPLT0065
    8 EBT(11)=EBT(11)+EBT(I)                                            EPLT0066
      IF(S(2221).GT.0.0) EBT(11)=S(2221)                                EPLT0067
C                     DETERMINE MAX FUNCTIONAL LOAD                     EPLT0068
      MXFCKW=MAX1(ECR(11),EBT(11))                                      EPLT0069
C                     CALC 24 HR KW AVERAGE LOAD                        EPLT0070
      EAV(1)=(0.00115*(FLDISP*VSUS)+7.63)*A                             EPLT0071
      EAV(2)=(0.0705*FLDISP-80.54)*E                                    EPLT0072
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      EAV(3)=0.3                                                        EPLT0073
      EAV(4)=5.4                                                        EPLT0074
      EAV(5)=0.3322*WGP4+143.17                                         EPLT0075
      EAV(6)=12.1                                                       EPLT0076
      EAV(7)=0.00462*FLDISP+123.03                                      EPLT0077
      EAV(8)=0.1021*FLDISP-114.19                                       EPLT0078
      IF(HTTYP.EQ.2.0) ECR(8)=0.1252*FLDISP+343.10                      EPLT0079
      EAV(9)=99.4                                                       EPLT0080
      EAV(10)=ELMARG*(EAV(1)+EAV(2)+EAV(3)+EAV(4)+EAV(5)+EAV(6)+EAV(7)+ EPLT0081
     1EAV(8)+EAV(9))                                                    EPLT0082
      DO 902 N=2222,2231                                                EPLT0083
      IF(S(N).EQ.0.0) GO TO 902                                         EPLT0084
      EAV(N-2221)=S(N)                                                  EPLT0085
  902 CONTINUE                                                          EPLT0086
      EAV(11)=0.0                                                       EPLT0087
      DO 10 I=1,10                                                      EPLT0088
   10 EAV(11)=EAV(11)+EAV(I)                                            EPLT0089
      IF(S(2232).GT.0.0) EAV(11)=S(2232)                                EPLT0090
      KW24AV=EAV(11)                                                    EPLT0091
      IF(KELEC.EQ.0) NLSD=NMSD=NHSD=NGTG=NSTG=0                         EPLT0092
C                     NOW SIZE ELECTRIC PLANT                           EPLT0093
      IF(KELEC.EQ.1) GO TO 800                                          EPLT0094
      GO TO 801                                                         EPLT0095
  800 IF(NSTG.EQ.0) GO TO 802                                           EPLT0096
C                     STEAM PLANT, SO STEAM GEN PLUS DIE OR G.T. EMER   EPLT0097
      KWSSER=NSTG*KWPRSG                                                EPLT0098
      KWEMER=(NLSD+NMSD+NHSD)*KWPRD+NGTG*KWPRGT                         EPLT0099
      KWINST=KWSSER+KWEMER                                              EPLT0100
      NGFCLD=MXFCKW/KWPRSG+1                                            EPLT0101
      NGAVG=KW24AV/KWPRSG+1                                             EPLT0102
      NSSG=NSTG                                                         EPLT0103
      NEMG=NLSD+NMSD+NHSD+NGTG                                          EPLT0104
      GO TO 850                                                         EPLT0105
C                     DIESEL, GAS TURB OR COGAS PLANT                   EPLT0106
  802 KWSSER=(NLSD+NMSD+NHSD)*KWPRD+NGTG*KWPRGT                         EPLT0107
      KWEMER=0                                                          EPLT0108
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      KWINST=KWSSER+KWEMER                                              EPLT0109
      KWGEN=MAXO(KWPRD,KWPRGT)                                          EPLT0110
      NGFCLD=MXFCKW/KWGEN+1                                             EPLT0111
      NGAVG=KW24AV/KWGEN+1                                              EPLT0112
      NSSG=NLSD+NMSD+NHSD+NGTG                                          EPLT0113
      NEMG=0                                                            EPLT0114
      GO TO 850                                                         EPLT0115
C                  GENERATOR NUMBER AND SIZE NOT GIVEN SO MUST CALC      EPLT0116
  801 IF(MXFCKW.GE.1000) GO TO 870                                      EPLT0117
      KWGEN=MXFCKW/2                                                    EPLT0118
      KWGEN=500                                                         EPLT0119
      IF(MXFCKW/2.LT.300) KWGEN=300                                     EPLT0120
      NGFCLD=2                                                          EPLT0121
      NGAVG=KW24AV/KWGEN+1                                              EPLT0122
      NSSG=3                                                            EPLT0123
      NEMG=2                                                            EPLT0124
      KWEMER=400                                                        EPLT0125
      KWSSER=KWGEN*NSSG                                                 EPLT0126
      GO TO 860                                                         EPLT0127
  870 NGFCLD=3                                                          EPLT0128
      NSSG=4                                                            EPLT0129
      NEMG=2                                                            EPLT0130
      KWEMER=600                                                        EPLT0131
      IF(MXFCKW.GE.1500) GO TO 871                                      EPLT0132
      KWGEN=500                                                         EPLT0133
      KWSSER=2000                                                       EPLT0134
      KWINST=2600                                                       EPLT0135
      NGAVG=KW24AV/KWGEN+1                                              EPLT0136
      GO TO 860                                                         EPLT0137
  871 IF(MXFCKW.GE.2250) GO TO 872                                      EPLT0138
      KWGEN=750                                                         EPLT0139
      KWSSER=3000                                                       EPLT0140
      KWINST=3600                                                       EPLT0141
      NGAVG=KW24AV/KWGEN+1                                              EPLT0142
      GO TO 860                                                         EPLT0143
  872 KWEMER=1000                                                       EPLT0144
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      IF(MXFCKW.GE.3000) GO TO 873                                      EPLT0145
      KWGEN=1000                                                        EPLT0146
      KWSSER=4000                                                       EPLT0147
      KWINST=5000                                                       EPLT0148
      NGAVG=KW24AV/KWGEN+1                                              EPLT0149
      GO TO 860                                                         EPLT0150
  873 KWEMER=1500                                                       EPLT0151
      IF(MXFCKW.GE.4500) GO TO 874                                      EPLT0152
      KWGEN=1500                                                        EPLT0153
      KWSSER=6000                                                       EPLT0154
      KWINST=7500                                                       EPLT0155
      NGAVG=KW24AV/KWGEN+1                                              EPLT0156
      GO TO 860                                                         EPLT0157
  874 IF(MXFCKW.GE.6000) GO TO 875                                      EPLT0158
      KWGEN=2000                                                        EPLT0159
      KWSSER=8000                                                       EPLT0160
      KWINST=9500                                                       EPLT0161
      NGAVG=KW24AV/KWGEN+1                                              EPLT0162
      GO TO 860                                                         EPLT0163
  875 KWEMER=2000                                                       EPLT0164
      IF(MXFCKW.GE.7500) GO TO 876                                      EPLT0165
      KWGEN=2500                                                        EPLT0166
      KWSSER=10000                                                      EPLT0167
      KWINST=12000                                                      EPLT0168
      NGAVG=KW24AV/KWGEN+1                                              EPLT0169
      GO TO 860                                                         EPLT0170
  876 KWGEN=2500                                                        EPLT0171
      NSSG=MXFCKW/KWGEN+2                                               EPLT0172
      KWSSER=NSSG*KWGEN                                                 EPLT0173
      KWINST=KWSSER+KWEMER                                              EPLT0174
      NGFCLD=NSSG-1                                                     EPLT0175
      NGAVG=KW24AV/KWGEN+1                                              EPLT0176
C                     GENERATORS SIZED ABOVE SO NOW DETERMINE TYPE      EPLT0177
  860 NGTG=NLSD=NMSD=NHTG=NSTG=0                                        EPLT0178
      KWPRD=KWPRGT=KWPRSG=0                                             EPLT0179
      IF(SSETYP.LE.1) GO TO 50                                          EPLT0180
```

```
      NEMG=0                                                            EPLT0181
      KWEMER=0                                                          EPLT0182
      KWINST=KWSSER                                                     EPLT0183
      GO TO (50,51,51,52,53,54),SSETYP                                  EPLT0184
   50 NSTG=NSSG                                                         EPLT0185
      KWPRSG=KWGEN                                                      EPLT0186
      GO TO (60,60,61,62,63),EMETYP                                     EPLT0187
   61 NLSD=NEMG                                                         EPLT0188
      KWPRD=KWEMER/NEMG                                                 EPLT0189
      GO TO 850                                                         EPLT0190
   62 NMSD=NEMG                                                         EPLT0191
      KWPRD=KWEMER/NEMG                                                 EPLT0192
      GO TO 850                                                         EPLT0193
   63 NHSD=NEMG                                                         EPLT0194
      KWPRD=KWEMER/NEMG                                                 EPLT0195
      GO TO 850                                                         EPLT0196
   60 NGTG=NEMG                                                         EPLT0197
      KWPRGT=KWEMER/NEMG                                                EPLT0198
      GO TO 850                                                         EPLT0199
   51 NGTG=NSSG                                                         EPLT0200
      KWPRGT=KWGEN                                                      EPLT0201
      GO TO 850                                                         EPLT0202
   52 NLSD=NSSG                                                         EPLT0203
      KWPRD=KWGEN                                                       EPLT0204
      GO TO 850                                                         EPLT0205
   53 NMSD=NSSG                                                         EPLT0206
      KWPRD=KWGEN                                                       EPLT0207
      GO TO 850                                                         EPLT0208
   54 NHSD=NSSG                                                         EPLT0209
      KWPRD=KWGEN                                                       EPLT0210
  850 CONTINUE                                                          EPLT0211
      RETURN                                                            EPLT0212
      END                                                               EPLT0213
```

```
      SUBROUTINE MACHLQ                                                 MALQ0001
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)                       MALQ0002
      INTEGER PPTYP,SSETYP,EMETYP                                       MALQ0003
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400) MALQ0004
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP   MALQ0005
      COMMON/GENSZ/KWSSER,KWEMER,KWINST,SSETYP,EMETYP,NLSD,NMSD,NHSD,   MALQ0006
     1NGTG,NSTG,KWPRD,KWPRGT,KWPRSG,NGFCLD,NGAVG,NSSG,NEMG,KELEC        MALQ0007
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR     MALQ0008
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE     MALQ0009
      COMMON/PEOPLE/NACC,NOFF,NCPO,NCREW,NFLAG,NTRP,NPASS,DUR,NACSC     MALQ0010
C                    POTABLE WATER                                      MALQ0011
      W(812)=0.053*NACC**1.214                                          MALQ0012
C                    RESERVE FEED WATER                                 MALQ0013
      GO TO (2,3,3,4,1,1,1,2),PPTYP                                     MALQ0014
    1 W(813)=0.0                                                        MALQ0015
      GO TO 10                                                          MALQ0016
    2 W(813)=0.2022*SHP**0.530                                          MALQ0017
      GO TO 10                                                          MALQ0018
    3 W(813)=0.000583*SHP**1.057                                        MALQ0019
      GO TO 10                                                          MALQ0020
    4 W(813)=0.00362*SHP**0.9466                                        MALQ0021
   10 CONTINUE                                                          MALQ0022
C                    LUBE OIL SHIP                                      MALQ0023
      GO TO (5,6,6,7,9,9,8,9),PPTYP                                     MALQ0024
    5 W(814)=.0000388*SHP+3.08                                          MALQ0025
      GO TO 20                                                          MALQ0026
    6 W(814)=0.00286*SHP**0.7649                                        MALQ0027
      GO TO 20                                                          MALQ0028
    7 W(814)=5.51E-6*SHP**1.387                                         MALQ0029
      GO TO 20                                                          MALQ0030
    8 W(814)=0.00398*SHP                                                MALQ0031
      GO TO 20                                                          MALQ0032
    9 W(814)=4.366*SHP**0.1122                                          MALQ0033
   20 CONTINUE                                                          MALQ0034
C                    FUEL OIL (NON-DIESEL)                              MALQ0035
      GO TO (32,32,32,31,33,33,34,35),PPTYP                             MALQ0036
```

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   31 W(816)=0.0                                                      MALQ0037
      GO TO 30                                                        MALQ0038
   32 AVEDPW=1.1*SHPE                                                 MALQ0039
      FRSTM=0.5882*AVEDPW+1303.92                                     MALQ0040
      W(816)=(ENDUR*FRSTM)/(VEND*2240.0)*1.18                         MALQ0041
      GO TO 30                                                        MALQ0042
   33 AVEDPW=1.1*SHPE                                                 MALQ0043
      IF(NSHFT.EQ.2) GO TO 40                                         MALQ0044
      NEEND=2                                                         MALQ0045
      IF(AVEDPW.LE.SHP/NE) NEEND=1                                    MALQ0046
      GO TO 41                                                        MALQ0047
   40 NEEND=4                                                         MALQ0048
      IF(AVEDPW.LE.2.*SHP/NE) NEEND=2                                 MALQ0049
   41 EDPWPE=AVEDPW/NEEND                                             MALQ0050
      SFCFP=-.0000101*SHP/NE+0.717                                    MALQ0051
      IF(PPTYP.EQ.6) SFCFP=-.0000101*SHP/NE+0.627                     MALQ0052
      SFCAED=SFCFP*(1.2298*(1.-EDPWPE/(SHP/NE))**1.6384+1.0)          MALQ0053
      WFPROP=ENDUR*AVEDPW*SFCAED/(VEND*2240.0)*1.18                   MALQ0054
      GO TO 50                                                        MALQ0055
   34 WFPROP=0.0                                                      MALQ0056
      GO TO 50                                                        MALQ0057
   35 FRCGAS=2589.0+0.288*SHP                                         MALQ0058
      WFPROP=ENDUR*FRCGAS/(VEND*2240.0)*1.18                          MALQ0059
   50 GO TO (30,61,61,62,62,62),SSETYP                                MALQ0060
   61 AVEDPW=KW24AV/(.8*.746)                                         MALQ0061
      AEDPWG=AVEDPW/NGAVG                                             MALQ0062
      SFCFP=-.0000101*(KWPRGT/(.8*.746))+0.717                        MALQ0063
      IF(SSETYP.EQ.3) SFCFP=-.0000101*(KWPRGT/(.8*.746))+0.627        MALQ0064
      SFCAED=SFCFP*(1.2298*(1.-AEDPWG/(KWPRGT/(.8*.746)))**1.6384+1.0) MALQ0065
      WFELEC=ENDUR*AVEDPW*SFCAED/(VEND*2240.0)*1.05                   MALQ0066
      GO TO 60                                                        MALQ0067
   62 WFELEC=0.0                                                      MALQ0068
   60 FRAUXB=1.044*NACC                                               MALQ0069
      WFAUXB=ENDUR*FRAUXB/(VEND*2240.0)*1.05                          MALQ0070
      W(816)=WFPROP+WFELEC+WFAUXB                                     MALQ0071
   30 CONTINUE                                                        MALQ0072
```

```
C                   DIESEL OIL                                              MALQ0073
      GO TO (71,71,71,71,72,72,73,72),PPTYP                                 MALQ0074
   71 W(817)=0.1432*KWEMER-5.60                                             MALQ0075
      GO TO 70                                                              MALQ0076
   72 WFPROP=0.0                                                            MALQ0077
      GO TO 75                                                              MALQ0078
   73 AVEDPW=1.1*SHPE                                                       MALQ0079
      IF(NSHFT.EQ.2) GO TO 76                                               MALQ0080
      NEEND=2                                                               MALQ0081
      IF(AVEDPW.LE.SHP/NE) NEEND=1                                          MALQ0082
      GO TO 77                                                              MALQ0083
   76 NEEND=4                                                               MALQ0084
      IF(AVEDPW.LE.2.*SHP/NE) NEEND=2                                       MALQ0085
   77 EDPWPE=AVEDPW/NEEND                                                   MALQ0086
      RATFP=EDPWPE/(SHP/NE)                                                 MALQ0087
      SFCAED=0.274*EXP(-5.166*RATFP)+0.359                                  MALQ0088
      WFPROP=ENDUR*AVEDPW*SFCAED/(VEND*2240.0)*1.18                         MALQ0089
   75 GO TO (81,81,81,82,82,82),SSETYP                                      MALQ0090
   81 WFELEC=0.0                                                            MALQ0091
      GO TO 85                                                              MALQ0092
   82 FRDIEG=1.8845*(KW24AV/NGAVG)**0.8273                                  MALQ0093
      WFELEC=ENDUR*FRDIEG*NGAVG/(VEND*2240.0)*1.05                          MALQ0094
   85 W(817)=WFPROP+WFELEC                                                  MALQ0095
   70 CONTINUE                                                              MALQ0096
      DO 100 I=1012,1022                                                    MALQ0097
      IF(S(I).GT.0.) W(I-200)=S(I)                                          MALQ0098
  100 CONTINUE                                                              MALQ0099
      RETURN                                                                MALQ0100
      END                                                                   MALQ0101
```

```
      SUBROUTINE MBSIZE
      REAL LBP,KGTRY,LENMB
      INTEGER PPTYP
      COMMON/MBDIM/DEPMB,LENMB,BEAMMB
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG
      IF(DEPMB.GT.0.0) GO TO 100
C                   DETERMINE TYPE PROP PLANT AND FIND MIN DEPTH
      GO TO (1,1,1,1,2,2,2,2),PPTYP
    1 CVK=.2*B-6.0
      HCOR=-10.0*CX+9.0
      HABCVK=0.00025*SHP/NSHFT+20.5
      IF(NB/NSHFT.GT.1) HABCVK=.000125*SHP/NSHFT+20.0
      DEPMB=CVK+HCOR+HABCVK
      GO TO 100
    2 HCOR=-10.0*CX+9.0
      CVK=.2*B-6.0
      HABCVK=19.0
      IF(NSHFT.GT.1) HABCVK=21.5
      DEPMB=CVK+HCOR+HABCVK
  100 RETURN
      END
```

```
      SUBROUTINE VOLUME(ERROR)                                          VOLM0001
      REAL LBP,KGTRY,LRD,LRD1,LENMB,LMB                                 VOLM0002
      INTEGER PPTYP,SSETYP,EMETYP                                       VOLM0003
      COMMON/MISC/FINST,HULMAT,SSMAT,PASTYP                             VOLM0004
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)                       VOLM0005
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)VOLM0006
      COMMON/VOLUM/V(400),VOLTOT,VOLSST,VOLHUL,VOLMB,FNDEN(400)         VOLM0007
      COMMON/GENSZ/KWSSER,KWEMER,KWINST,SSETYP,EMETYP,NLSD,NMSD,NHSD,   VOLM0008
     1NGTG,NSTG,KWPRD,KWPRGT,KWPRSG,NGFCLD,NGAVG,NSSG,NEMG,KELEC        VOLM0009
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRYVOLM0010
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR     VOLM0011
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE     VOLM0012
      COMMON/MBDIM/DEPMB,LENMB,BEAMMB                                   VOLM0013
      COMMON/PEOPLE/NACC,NOFF,NCPO,NCREW,NFLAG,NTRP,NPASS,DUR,NACSC     VOLM0014
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG              VOLM0015
      DIMENSION VVH(400),VVS(400),VVHH(400),VVSS(400)                   VOLM0016
      ERROR=0.0                                                         VOLM0017
      FLDISP=DPTRY                                                      VOLM0018
      KNDEX=0                                                           VOLM0019
      DECKHT=0.                                                         VOLM0020
      LRD=0.                                                            VOLM0021
      LRD1=0.                                                           VOLM0022
      NSHEER=0                                                          VOLM0023
C                     DEVELOP ACCEPTABLE SHEER LINE                     VOLM0024
   13 CALL SHEER(DEPMB,F0,F10,F20,D0,D10,D20,LBP,H,DECKHT,NSHEER)       VOLM0025
      IF(NSHEER.EQ.1) GO TO 1000                                        VOLM0026
      AREA=LBP/6.*(F0+F20+4*F10)                                        VOLM0027
      FAVG=AREA/LBP                                                     VOLM0028
      DAVG=FAVG+H                                                       VOLM0029
      F7=-.018828*(DAVG/H)**2+.18098*DAVG/H+.714599                     VOLM0030
C                     USING FLARE FACTOR ABOVE CALC TOTAL HULL VOLUME   VOLM0031
      HVAW=LBP*B*CWP*FAVG*F7                                            VOLM0032
      HVBW=LBP*B*H*CP*CX                                                VOLM0033
      THV=HVAW+HVBW                                                     VOLM0034
      DO 17 I=1,400                                                     VOLM0035
   17 V(I)=0.0                                                          VOLM0036
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C          ESTIMATE MACHBX LENGTH                                          VOLM0037
      IF(LENMB.GT.0.0) GO TO 34                                            VOLM0038
      GO TO (21,21,21,22,23,23,24,23),PPTYP                                VOLM0039
   21 V(321)=30851.+1.472*SHP+7.735*KWINST                                 VOLM0040
      GO TO 30                                                             VOLM0041
   22 V(321)=0.2685*(SHP+KWINST/(.8*.746))**1.225                          VOLM0042
      GO TO 30                                                             VOLM0043
   23 V(321)=0.8346*(SHP+KWINST/(.8*.746))**1.084                          VOLM0044
      GO TO 30                                                             VOLM0045
   24 V(321)=893.21*SHP**0.4955                                            VOLM0046
   30 IF(S(2121).GT.0.0) V(321)=S(2121)                                    VOLM0047
      AM=B*H*CX+B*F10                                                      VOLM0048
      CPM=0.95                                                             VOLM0049
      IF(S(2299).GT.0.0) CPM=S(2299)                                       VOLM0050
      LMB=V(321)/(AM*CPM)                                                  VOLM0051
      VOLMB=V(321)                                                         VOLM0052
      GO TO 14                                                             VOLM0053
   34 CPM=0.95                                                             VOLM0054
      IF(S(2299).GT.0.0) CPM=S(2299)                                       VOLM0055
      V(321)=LENMB*CPM*(BEAMMB*H*CX+B*(DEPMB-H))                           VOLM0056
      LMB=LENMB                                                            VOLM0057
      VOLMB=V(321)                                                         VOLM0058
C         MIN TANKAGE VOLUME IS CALC                                       VOLM0059
   14 T=(-.9037115+.2139727*D10-1.38263E-2*D10**2+4.008058E-4*D10**3       VOLM0060
     1-5.489481E-6*D10**4+2.892153E-8*D10**5)*CP/.58*CX/.814*(1.11*LMB/    VOLM0061
     2LBP+.667)                                                            VOLM0062
      AHVOM=THV-V(321)                                                     VOLM0063
      ATVOM=T*AHVOM                                                        VOLM0064
C                   DETERMINE ALL VOLUMES REQUIRED                         VOLM0065
C                   CALCULATE VOLUME OF PAYLOAD INPUT                      VOLM0066
      DECKHT=9.0                                                           VOLM0067
      IF(S(2274).GT.0.) DECKHT=S(2274)                                     VOLM0068
      DO 40 I=1,400                                                        VOLM0069
   40 VVH(I)=VVS(I)=VVHH(I)=VVSS(I)=0                                      VOLM0070
      DO 41 I=1,100                                                        VOLM0071
      IF(Q(I).LT.0.) GO TO 44                                              VOLM0072
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      IF(IT(I).EQ.0) GO TO 41                                           VOLM0073
      IF(P(2,IT(I)).EQ.0.) GO TO 41                                     VOLM0074
      VVSS(P(2,IT(I)))=Q(I)*P(6,IT(I))*DECKHT                           VOLM0075
      VVS(P(2,IT(I)))=VVS(P(2,IT(I)))+VVSS(P(2,IT(I)))                  VOLM0076
      VVHH(P(2,IT(I)))=Q(I)*P(7,IT(I))*DECKHT                           VOLM0077
      VVH(P(2,IT(I)))=VVH(P(2,IT(I)))+VVHH(P(2,IT(I)))                  VOLM0078
      V(P(2,IT(I)))=VVS(P(2,IT(I)))+VVH(P(2,IT(I)))                     VOLM0079
   41 CONTINUE                                                          VOLM0080
   44 DO 42 K=2301,2499,10                                              VOLM0081
      IF(S(K).EQ.0.) GO TO 42                                           VOLM0082
      VVSS(S(K))=S(K+4)*DECKHT                                          VOLM0083
      VVS(S(K))=VVS(S(K))+VVSS(S(K))                                    VOLM0084
      VVHH(S(K))=S(K+5)*DECKHT                                          VOLM0085
      VVH(S(K))=VVH(S(K))+VVHH(S(K))                                    VOLM0086
      V(S(K))=VVS(S(K))+VVH(S(K))                                       VOLM0087
   42 CONTINUE                                                          VOLM0088
C                    CALC VOLUME OF NON INPUT FUNCTIONS                 VOLM0089
      V(116)=0.332*FLDISP+1437.+V(116)                                  VOLM0090
      IF(NTRP.GT.0) V(140)=572.36*NTRP**0.8906                          VOLM0091
      IF(NFLAG.GT.0) V(160)=572.36*NFLAG**0.8906                        VOLM0092
      IF(NPASS.GT.0) V(170)=572.36*NPASS**0.8906                        VOLM0093
      DO 43 J=2250,2273                                                 VOLM0094
      IF(S(J).EQ.0.0) S(J)=1.0                                          VOLM0095
   43 CONTINUE                                                          VOLM0096
      V(211)=(777.77*NOFF-3906.56)*S(2250)                              VOLM0097
      IF(NOFF.GT.0) V(212)=(526.83*NOFF**0.6533)*S(2251)                VOLM0098
      IF(NOFF.GT.0) V(213)=(128.92*NOFF**0.8878)*S(2252)                VOLM0099
      V(214)=(255.15*NCPO+488.10)*S(2253)                               VOLM0100
      V(215)=(89.91*NCPO+584.75)*S(2254)                                VOLM0101
      V(216)=(53.78*NCPO+588.04)*S(2255)                                VOLM0102
      V(217)=(129.45*NCREW+9828.35)*S(2256)                             VOLM0103
      V(218)=(23.12*NCREW+4429.66)*S(2257)                              VOLM0104
      V(219)=(26.31*NCREW+573.84)*S(2258)                               VOLM0105
      IF(NACC.GT.0) V(221)=(3.33*NACC**1.088)*S(2259)                   VOLM0106
      IF(NACC.GT.0) V(222)=(107.22*NACC**0.7933)*S(2260)                VOLM0107
      V(223)=(18.33*NACC-2124.47)*S(2261)                               VOLM0108
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      V(224)=(16.30*NACC+1316.03)*S(2262)                               VOLM0109
      V(225)=(2.91*NACC+1473.42)*S(2263)                                VOLM0110
      IF(NACC*DUR.GT.0.) V(231)=(0.8642*(NACC*DUR)**0.965)*S(2264)      VOLM0111
      V(232)=(17.22*NACC-623.12)*S(2265)                                VOLM0112
      V(233)=(7.172*NACC+793.50)*S(2266)                                VOLM0113
      V(311)=(0.00749*LBP**2.258)*S(2267)                               VOLM0114
      V(312)=0.417*FLDISP+1062.74                                       VOLM0115
      V(313)=(0.8889*FLDISP+541.68)*S(2268)                             VOLM0116
      GO TO (51,51,51,52,54,54,53,54),PPTYP                             VOLM0117
   51 V(322)=0.4547*SHP**0.9134                                         VOLM0118
      GO TO 50                                                          VOLM0119
   52 V(322)=2000.0                                                     VOLM0120
      GO TO 50                                                          VOLM0121
   53 V(322)=8.32*SHP**0.6667                                           VOLM0122
      GO TO 50                                                          VOLM0123
   54 V(322)=.00951*(SHP+KWINST/(.8*.746))**1.355                       VOLM0124
   50 CONTINUE                                                          VOLM0125
      IF(NSHFT.EQ.1) GO TO 60                                           VOLM0126
      V(323)=2.10E-5*LBP**3.034                                         VOLM0127
      GO TO 61                                                          VOLM0128
   60 GO TO (62,62,62,62,63,63,63,63),PPTYP                             VOLM0129
   62 V(323)=15.90*LBP-3688.67                                          VOLM0130
      GO TO 61                                                          VOLM0131
   63 V(323)=0.0                                                        VOLM0132
   61 CONTINUE                                                          VOLM0133
      V(324)=0.0183*(FLDISP*VSUS)+2248.70                               VOLM0134
      V(325)=(2.092*FLDISP-1516.62)*S(2269)                             VOLM0135
      V(331)=0.6413*LBP**1.432                                          VOLM0136
      V(341)=(0.8036*FLDISP-200.37)*S(2270)                             VOLM0137
      V(342)=(0.1943*FLDISP+331.42)*S(2271)                             VOLM0138
      V(343)=(0.0291*FLDISP**1.284)*S(2272)                             VOLM0139
      IF(W(816).GT.0.) V(351)=105.85*W(816)**0.8532                     VOLM0140
      IF(PPTYP.EQ.4) V(351)=0.0                                         VOLM0141
      IF(W(813).GT.0.) V(352)=0.5324*W(813)**1.9287                     VOLM0142
      V(353)=39.0*W(814)                                                VOLM0143
      IF(W(817).GT.0.) V(354)=27.93*W(817)**1.0798                      VOLM0144
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      V(355)=40.0*W(820)                                                VOLM0145
      V(356)=0.5353*NACC*DUR+4422.87                                    VOLM0146
      V(361)=40.0*W(822)                                                VOLM0147
      V(362)=0.450*FLDISP-145.90                                        VOLM0148
      V(363)=2.38E-5*FLDISP**2.314                                      VOLM0149
      V(370)=0.0                                                        VOLM0150
      DO 90 I=1900,2199                                                 VOLM0151
      IF(S(I).GT.0.0) V(I-1800)=S(I)                                    VOLM0152
   90 CONTINUE                                                          VOLM0153
      IF(V(121)+V(122)+V(123)+V(124)+V(125)+V(126)+V(128).GT.0.)        VOLM0154
     1V(127)=0.3577*(V(121)+V(122)+V(123)+V(124)+V(125)+V(126)+V(128))  VOLM0155
     2**0.8958                                                          VOLM0156
      IF(S(1927).GT.0.0) V(127)=S(1927)                                 VOLM0157
C                     TANKAGE VOLUME REQUIRED                           VOLM0158
      VTKREQ=V(134)+V(233)+V(351)+V(352)+V(353)+V(354)+V(355)+V(361)    VOLM0159
     1+V(362)+V(363)+V(364)+V(365)                                      VOLM0160
      RTAV=0.0                                                          VOLM0161
      IF(VTKREQ.GT.ATVOM) RTAV=VTKREQ-ATVOM                             VOLM0162
      TANKVL=ATVOM+RTAV                                                 VOLM0163
      IF(ATVOM.GT.VTKREQ) V(363)=V(363)+ATVOM-VTKREQ                    VOLM0164
      AVAV=AHVOM-TANKVL                                                 VOLM0165
C         AVAV=ACT AVAILABLE HULL ARRG VOL (THV-V(321)-TANKVL)          VOLM0166
      VOLTOT=0.0                                                        VOLM0167
      DO 91 J=100,400                                                   VOLM0168
      VOLTOT=VOLTOT+V(J)                                                VOLM0169
   91 CONTINUE                                                          VOLM0170
      VOLTOT=VOLTOT-V(370)                                              VOLM0171
      V(370)=(0.130*VOLTOT**0.9233)*S(2273)                             VOLM0172
      IF(PASTYP.EQ.2.0) V(370)=(90.90*VOLTOT**0.4932)*S(2273)           VOLM0173
      IF(S(2170).GT.0.0) V(370)=S(2170)                                 VOLM0174
C                     NOW GET TOTAL INTERNAL VOLUME REQUIRED            VOLM0175
      VOLTOT=VOLTOT+V(370)                                              VOLM0176
C                     CALC VOLUME REQUIRED IN HULL AND IN SUPERSTRUCTURE VOLM0177
C              HAVE ALREADY TAKEN OUT MACH BOX & TANKAGE VOLUME FROM HULL VOLM0178
C              NOW CALC REQUIRED SUPERSTRUCTURE VOLUME                  VOLM0179
      VOMPSS=0.                                                         VOLM0180
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      DO 200 I=1,400                                                    VOLM0181
      VOMPSS=VOMPSS+VVS(I)                                              VOLM0182
  200 CONTINUE                                                          VOLM0183
      RSSV=VOMPSS+V(160)+V(311)*.7+V(322)*.8+.25*V(325)+V(332)+V(357)+  VOLM0184
     1V(390)+.2*V(370)                                                  VOLM0185
      DHV=.00163*LBP**3                                                 VOLM0186
      IF(RSSV.GT.DHV) GO TO 1000                                        VOLM0187
      TAAV=DHV+AVAV                                                     VOLM0188
      TRAV=VOLTOT-TANKVL-V(321)                                         VOLM0189
      IF(TRAV.GT.TAAV) GO TO 10                                         VOLM0190
      DHSV=.0008*LBP**3                                                 VOLM0191
      DHAMIN=AMAX1(DHSV,RSSV)                                           VOLM0192
      TAAV=DHAMIN+AVAV                                                  VOLM0193
      IF(TRAV.GT.TAAV) GO TO 11                                         VOLM0194
      IF(DHSV.GT.RSSV) V(390)=V(390)+TAAV-AMAX1(TRAV,RSSV+AVAV)         VOLM0195
      IF(RSSV.GT.DHSV) V(380)=V(380)+TAAV-TRAV                          VOLM0196
      DHSV=DHAMIN                                                       VOLM0197
   12 DHV=DHSV                                                          VOLM0198
      ENCVOL=DHV+THV                                                    VOLM0199
      VOLSST=DHV                                                        VOLM0200
      VOLHUL=THV                                                        VOLM0201
      VOLTOT=ENCVOL                                                     VOLM0202
      RETURN                                                            VOLM0203
   11 DHSV=TRAV-AVAV                                                    VOLM0204
      GO TO 12                                                          VOLM0205
C                   ADD A RAISED DECK IF REQUIRED                       VOLM0206
   10 RHAV=TRAV-DHV                                                     VOLM0207
      RDAV=RHAV-AVAV                                                    VOLM0208
      X1=(RDAV/DECKHT)/(B*LBP)                                          VOLM0209
      IF(X1.GT..7) GO TO 1                                              VOLM0210
      IF(X1.GT..2) GO TO 2                                              VOLM0211
      LRD=-3.22*X1*X1+2.031*X1-.0184                                    VOLM0212
      GO TO 3                                                           VOLM0213
    1 LRD=.463*X1*X1+.446*X1+.22                                        VOLM0214
      GO TO 3                                                           VOLM0215
    2 LRD=X1+.059                                                       VOLM0216
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    3 LRD=LRD*LBP                                                              VOLM0217
      IF(ABS(LRD-LRD1).LT..05*LBP) GO TO 15                                    VOLM0218
      IF(KNDEX.GT.20) GO TO 1000                                               VOLM0219
      KNDEX=KNDEX+1                                                            VOLM0220
      LRD1=LRD                                                                 VOLM0221
      GO TO 13                                                                 VOLM0222
C                     CHECK TO SEE IF RAISED DECK LENGTH IS BETWEEN LIMITS     VOLM0223
   15 C1=.4*LBP                                                                VOLM0224
      C2=.6*LBP                                                                VOLM0225
      AVAV=RHAV                                                                VOLM0226
      IF(LRD.LT.C1.OR.LRD.GT.C2) GO TO 4                                       VOLM0227
      AVAV=AVAV+(C2-LRD)*B*DECKHT                                              VOLM0228
      RDAV=RDAV+(C2-LRD)*B*DECKHT                                              VOLM0229
      IF(DHV-RSSV.GT.(C2-LRD)*B*DECKHT) GO TO 5                                VOLM0230
      DHV=RSSV                                                                 VOLM0231
      V(380)=V(380)+(C2-LRD)*B*DECKHT-(DHV-RSSV)                               VOLM0232
      GO TO 6                                                                  VOLM0233
    5 DHV=DHV-(C2-LRD)*B*DECKHT                                                VOLM0234
    6 CONTINUE                                                                 VOLM0235
      LRD=C2                                                                   VOLM0236
C                     DETERMINE CORRECTED VALUES OF VOLUME.                    VOLM0237
    4 THV=THV+RDAV                                                             VOLM0238
      VOLHUL=THV                                                               VOLM0239
      ENCVOL=DHV+THV                                                           VOLM0240
      VOLTOT=ENCVOL                                                            VOLM0241
      VOLSST=DHV                                                               VOLM0242
      RETURN                                                                   VOLM0243
 1000 ERROR=1.0                                                                VOLM0244
      RETURN                                                                   VOLM0245
      END                                                                      VOLM0246
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      SUBROUTINE SHEER(DMB,F0,F10,F20,D0,D10,D20,LEN,H,DECKHT,NSHEER)   SHER0001
      REAL LEN                                                          SHER0002
      KOUNT=0                                                           SHER0003
      D10=DMB                                                           SHER0004
      IF(D10.LT.LEN/16.) D10=LEN/16.                                    SHER0005
      F0=1.011827*(100.*H/LEN)-.000636215*LEN+2.780649                  SHER0006
      F0=LEN*F0/100.                                                    SHER0007
      F0=F0-DECKHT                                                      SHER0008
      D0=F0+H                                                           SHER0009
      F20=.01*LEN*(2.125+.00125*LEN)                                    SHER0010
      D20=F20+H                                                         SHER0011
    7 S0=D0-D10                                                         SHER0012
      R0=S0/LEN                                                         SHER0013
      IF(R0.LT..01) GO TO 1                                             SHER0014
      IF(R0.GT..03) GO TO 2                                             SHER0015
    6 S20=D20-D10                                                       SHER0016
      R20=S20/LEN                                                       SHER0017
      IF(KOUNT.GT.20) GO TO 8                                           SHER0018
      KOUNT=KOUNT+1                                                     SHER0019
      IF(R20.LT..001) GO TO 3                                           SHER0020
      IF(R20.GT..0075) GO TO 4                                          SHER0021
      GO TO 5                                                           SHER0022
    1 S0=.01*LEN                                                        SHER0023
      D0=S0+D10                                                         SHER0024
      GO TO 6                                                           SHER0025
    2 S0=.03*LEN                                                        SHER0026
      D10=D0-S0                                                         SHER0027
      GO TO 6                                                           SHER0028
    3 S20=.001*LEN                                                      SHER0029
      D20=D10+S20                                                       SHER0030
      GO TO 5                                                           SHER0031
    4 S20=.0075*LEN                                                     SHER0032
      D10=D20-S20                                                       SHER0033
      GO TO 7                                                           SHER0034
    5 F0=D0-H                                                           SHER0035
      F20=D20-H                                                         SHER0036
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      F10=D10-H                                                         SHER0037
      RETURN                                                            SHER0038
    8 NSHEER=1                                                          SHER0039
      RETURN                                                            SHER0040
      END                                                               SHER0041
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```
      SUBROUTINE WEIGHT
      REAL LBP,KGTRY
      INTEGER PPTYP,SSETYP,EMETYP
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)
      COMMON/VOLUM/V(400),VOLTOT,VOLSST,VOLHUL,VOLMB,FNDEN(400)
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP
      COMMON/GENSZ/KWSSER,KWEMER,KWINST,SSETYP,EMETYP,NLSD,NMSD,NHSD,
     1NGTG,NSTG,KWPRD,KWPRGT,KWPRSG,NGFCLD,NGAVG,NSSG,NEMG,KELEC
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE
      COMMON/PEOPLE/NACC,NOFF,NCPO,NCREW,NFLAG,NTRP,NPASS,DUR,NACSC
      COMMON/MISC/FINST,HULMAT,SSMAT,PASTYP
      COMMON/WTGRPS/WTGP1,WTGP2,WTGP3,WTGP4,WTGP5,WTGP6,WTGP7,VRLOAD,
     1DISPLS,WTMARG,WBHS,WSS,WDHS,WARM,WFFL,WFG4,WFG5,VOLSHP,WTSHIP
C           CALC HULL STRUCTURE WEIGHTS --GROUP 1
C           SET HULL MATERIAL
      C=1.0
      IF(HULMAT.EQ.2.0) C=0.55
      FLDISP=DPTRY
      W(100)=(0.0677*FLDISP+25.26)*C
      W(101)=(0.0532*FLDISP-55.38)*C+.3*W(794)
      W(102)=0.0
      IF(FLDISP.GT.4600.) W(102)=(.0120*FLDISP+9.27)*C
      W(103)=(.00581*FLDISP**1.159)*C
      W(107)=(.0694*FLDISP-62.51)*C
      W(111)=.00199*VOLSST-16.44+.2*W(794)
      IF(SSMAT.EQ.2.0) W(111)=.00778*VOLSST**.820+.2*W(794)
      GO TO (2,1,6,4,5,5,3,5),PPTYP
    1 W(112)=(.00101*SHP/(NB*NSHFT)-3.51)*NB*NSHFT*C
      GO TO 10
    2 W(112)=(0.5428*SHP**.3348)*C
      GO TO 10
    3 W(112)=(.00204*SHP)*C
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      GO TO 10                                                          WGHT0037
    4 W(112)=(.000818*SHP/(NR*NSHFT)+40.65)*NR*NSHFT*C                  WGHT0038
      GO TO 10                                                          WGHT0039
    5 W(112)=(.000239*SHP/(NE*NSHFT)+16.18)*NE*NSHFT*C                  WGHT0040
      GO TO 10                                                          WGHT0041
    6 W(112)=.000714*SHP*C                                              WGHT0042
   10 CONTINUE                                                          WGHT0043
      W(113)=(.000189*VOLHUL-11.68)*C+.3*W(794)                         WGHT0044
      W(114)=(.000285*VOLHUL+22.83)*C                                   WGHT0045
      IF(PPTYP.EQ.4) W(114)=(.000658*VOLHUL-115.89)*C                   WGHT0046
      W(115)=5.27E-5*VOLTOT-4.47+.2*W(794)                              WGHT0047
      W(119)=(7.08E-5*VOLTOT+0.94)*C                                    WGHT0048
      W(120)=8.42E-8*VOLMB**1.53                                        WGHT0049
      IF(PPTYP.GE.5) W(120)=3.03E-8*VOLMB**1.56                         WGHT0050
      W(122)=0.0                                                        WGHT0051
      IF(FLDISP.GE.7600.) W(122)=.00342*FLDISP-18.51                    WGHT0052
      W(123)=3.83E-5*VOLTOT-1.89                                        WGHT0053
      W(125)=.000278*FLDISP+3.62                                        WGHT0054
      W(150)=(.000527*VOLTOT**.8314)*C                                  WGHT0055
      WTGP1=0.0                                                         WGHT0056
      DO 20 I=300,351                                                   WGHT0057
      IF(S(I).GT.0.) W(I-200)=S(I)                                      WGHT0058
   20 CONTINUE                                                          WGHT0059
      DO 21 J=100,151                                                   WGHT0060
      WTGP1=WTGP1+W(J)                                                  WGHT0061
   21 CONTINUE                                                          WGHT0062
C               CALC PROPULSION WEIGHTS --GROUP 2                       WGHT0063
      GO TO (31,32,33,34,35,35,36,37),PPTYP                             WGHT0064
   31 W(200)=.00288*SHP+21.92                                           WGHT0065
      W(201)=.00175*SHP+13.25                                           WGHT0066
      W(202)=.000766*SHP+2.98                                           WGHT0067
      W(204)=1.05E-4*SHP+6.50                                           WGHT0068
      W(205)=.000181*SHP+3.18                                           WGHT0069
      W(206)=4.0*NSHFT                                                  WGHT0070
      W(207)=.000586*SHP-5.68                                           WGHT0071
      W(208)=.000564*SHP+7.48                                           WGHT0072
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      W(209)=.000192*(SHP+KWINST/(.8*.746))+4.02                        WGHT0073
      W(210)=.00882*W(816)+3.25                                         WGHT0074
      W(211)=.000156*SHP+4.82                                           WGHT0075
      W(250)=5.0                                                        WGHT0076
      IF(NSHFT.GT.1) W(250)=10.0                                        WGHT0077
      W(251)=.000668*SHP+12.14                                          WGHT0078
      GO TO 40                                                          WGHT0079
   32 W(200)=.00234*SHP+48.09                                           WGHT0080
      W(201)=.00143*SHP+17.92                                           WGHT0081
      W(202)=.000457*SHP+2.57                                           WGHT0082
      W(204)=.000119*SHP+12.22                                          WGHT0083
      W(205)=.000136*SHP+14.14                                          WGHT0084
      W(206)=4.0*NSHFT                                                  WGHT0085
      W(207)=.000544*SHP-1.70                                           WGHT0086
      W(208)=.000610*SHP+10.42                                          WGHT0087
      W(209)=.000192*(SHP+KWINST/(.8*.746))+4.02                        WGHT0088
      W(210)=.00882*W(816)+3.25                                         WGHT0089
      W(211)=.000156*SHP+4.82                                           WGHT0090
      W(250)=5.0                                                        WGHT0091
      IF(NSHFT.GT.1) W(250)=10.0                                        WGHT0092
      W(251)=.000668*SHP+12.14                                          WGHT0093
      GO TO 40                                                          WGHT0094
   33 W(200)=.00234*SHP-14.0                                            WGHT0095
      W(201)=.00143*SHP+17.92                                           WGHT0096
      W(202)=.000457*SHP+2.57                                           WGHT0097
      W(204)=.000119*SHP+10.14                                          WGHT0098
      W(205)=.000136*SHP+6.54                                           WGHT0099
      W(206)=4.0*NSHFT                                                  WGHT0100
      W(207)=.000544*SHP-1.70                                           WGHT0101
      W(208)=.000610*SHP+10.42                                          WGHT0102
      W(209)=.000192*(SHP+KWINST/(.8*.746))+4.02                        WGHT0103
      W(210)=.00882*W(816)+3.25                                         WGHT0104
      W(211)=.000156*SHP+4.82                                           WGHT0105
      W(250)=5.0                                                        WGHT0106
      IF(NSHFT.GT.1) W(250)=10.0                                        WGHT0107
      W(251)=.000668*SHP+12.14                                          WGHT0108
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      GO TO 40                                                          WGHT0109
   34 W(200)=.000183*SHP**1.456                                         WGHT0110
      W(201)=.000761*SHP**1.119                                         WGHT0111
      W(202)=.00923*SHP**.7935                                          WGHT0112
      W(204)=0.0                                                        WGHT0113
      W(205)=0.0                                                        WGHT0114
      W(206)=4.0*NSHFT                                                  WGHT0115
      W(207)=33.52*SHP**.0392                                           WGHT0116
      W(208)=2.592*SHP**.3105                                           WGHT0117
      W(209)=1.32E-8*(SHP+KWINST/(.8*.746))**1.8642                     WGHT0118
      W(210)=0.0                                                        WGHT0119
      W(211)=.0443*SHP**.560                                            WGHT0120
      W(250)=45.0                                                       WGHT0121
      W(251)=.0972*(W(200)+W(201)+W(202)+W(207)+W(208)+W(209)+W(211))   WGHT0122
     1-69.57                                                            WGHT0123
      GO TO 40                                                          WGHT0124
   35 W(200)=0.0                                                        WGHT0125
      W(201)=.00283*SHP+2.68                                            WGHT0126
      W(202)=0.0                                                        WGHT0127
      W(204)=.000196*SHP                                                WGHT0128
      IF(SSETYP.LT.4.AND.SSETYP.GT.1) W(204)=.000503*(SHP+KWINST/(.8*   WGHT0129
     1.746))                                                            WGHT0130
      W(205)=.00140*(SHP+KWINST/(.8*.746))                              WGHT0131
      IF(SSETYP.GT.3) W(205)=.000317*SHP                                WGHT0132
      W(206)=5.25E-5*SHP+3.90                                           WGHT0133
      W(207)=0.0                                                        WGHT0134
      W(208)=0.0                                                        WGHT0135
      W(209)=0.0                                                        WGHT0136
      IF(SSETYP.GT.3) W(209)=.000890*KWINST                             WGHT0137
      W(210)=.00882*W(816)+3.25                                         WGHT0138
      W(211)=3.10E-7*SHP**1.641                                         WGHT0139
      W(250)=5.0                                                        WGHT0140
      IF(NSHFT.GT.1) W(250)=10.0                                        WGHT0141
      W(251)=1.152*(W(209)+W(210)+W(211))-10.10                         WGHT0142
      GO TO 40                                                          WGHT0143
   36 W(200)=0.0                                                        WGHT0144
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      W(201)=.0124*SHP+5.25                                             WGHT0145
      W(202)=0.0                                                        WGHT0146
      W(204)=0.0                                                        WGHT0147
      W(205)=.00209*SHP                                                 WGHT0148
      W(206)=.00144*SHP                                                 WGHT0149
      W(207)=0.0                                                        WGHT0150
      W(208)=0.0                                                        WGHT0151
      W(209)=.00111*(SHP+KWINST/(.8*.746))                              WGHT0152
      W(210)=.00882*W(817)+3.25                                         WGHT0153
      W(211)=.00193*SHP                                                 WGHT0154
      W(250)=5.0                                                        WGHT0155
      IF(NSHFT.GT.1) W(250)=10.0                                        WGHT0156
      W(251)=.618*(W(209)+W(210)+W(211))                                WGHT0157
      GO TO 40                                                          WGHT0158
   37 W(200)=.000883*SHP                                                WGHT0159
      W(201)=.00247*SHP                                                 WGHT0160
      W(202)=.000533*SHP                                                WGHT0161
      W(204)=.000267*SHP                                                WGHT0162
      W(205)=.00140*(SHP+KWINST/(.8*.746))                              WGHT0163
      IF(SSETYP.GT.3) W(205)=.000317*SHP                                WGHT0164
      W(206)=.0005*SHP                                                  WGHT0165
      W(207)=8.33E-5*SHP                                                WGHT0166
      W(208)=1.833E-4*SHP                                               WGHT0167
      W(209)=.0003*SHP                                                  WGHT0168
      W(210)=.00882*W(816)+3.25                                         WGHT0169
      W(211)=.000267*SHP                                                WGHT0170
      W(250)=5.0                                                        WGHT0171
      IF(NSHFT.GT.1) W(250)=10.0                                        WGHT0172
      W(251)=.000633*SHP                                                WGHT0173
   40 CONTINUE                                                          WGHT0174
C              CALC WEIGHT OF SHAFTING, BEARINGS & PROPELLERS           WGHT0175
      F=0.20                                                            WGHT0176
      IF(PPTYP.LE.4) F=0.36                                             WGHT0177
      IF(DPROP.GT.0.) GO TO 38                                          WGHT0178
      DPROP=2.603*H**0.629                                              WGHT0179
      IF(NSHFT.GT.1) DPROP=4.281*H**.4283                               WGHT0180
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38 IF(RPM.GT.0.) GO TO 39                                                  WGHT0181
   RPM=96.12*VSUS/DPROP+52.15                                              WGHT0182
39 IF(SHFTYP.EQ.2.) GO TO 41                                               WGHT0183
   IF(PRPTYP.EQ.1.) GO TO 42                                               WGHT0184
   WSHAFT=F*LBP*NSHFT*(1.+.5*NSHFT)*(.0134*(SHP/(NSHFT*RPM))**(2./3.       WGHT0185
  1))**.9497                                                               WGHT0186
   GO TO 45                                                                WGHT0187
42 WSHAFT=F*LBP*NSHFT*(.0134*(SHP/(NSHFT*RPM))**(2./3.))**.9497            WGHT0188
   GO TO 45                                                                WGHT0189
41 WSHAFT=F*LBP*NSHFT*(.0275*(SHP/(NSHFT*RPM))**(2./3.))**.8768            WGHT0190
45 CONTINUE                                                                WGHT0191
   WPROP=(.00146*DPROP**3.279)*NSHFT                                       WGHT0192
   IF(PRPTYP.EQ.2.) WPROP=(.00314*DPROP**3.128)*NSHFT                      WGHT0193
   WBRGS=.15*(WSHAFT+WPROP)                                                WGHT0194
   W(203)=WSHAFT+WPROP+WBRGS                                               WGHT0195
   WTGP2=0.0                                                               WGHT0196
   DO 50 I=400,451                                                         WGHT0197
   IF(S(I).GT.0.) W(I-200)=S(I)                                            WGHT0198
50 CONTINUE                                                                WGHT0199
   DO 51 J=200,251                                                         WGHT0200
   WTGP2=WTGP2+W(J)                                                        WGHT0201
51 CONTINUE                                                                WGHT0202
C           CALC ELECTRIC PLANT WEIGHTS --GROUP 3                          WGHT0203
   W(300)=NLSD*(.0424*KWPRD+.44)+NMSD*(.0240*KWPRD+.05)+NHSD*(.0137*       WGHT0204
  1KWPRD+.32)+NGTG*(.00424*KWPRGT+16.4)+NSTG*(.0167*KWPRSG-1.63)           WGHT0205
   W(301)=.0030*KWINST+2.61                                                WGHT0206
   W(302)=2.15E-8*VOLTOT**1.623                                            WGHT0207
   IF(VOLTOT.GE.400000.) W(302)=.000170*VOLTOT-48.83                       WGHT0208
   W(303)=3.67E-5*VOLTOT-0.73                                              WGHT0209
   W(350)=.000348*KWINST+1.96                                              WGHT0210
   WTGP3=0.0                                                               WGHT0211
   DO 52 I=500,551                                                         WGHT0212
   IF(S(I).GT.0.) W(I-200)=S(I)                                            WGHT0213
52 CONTINUE                                                                WGHT0214
   DO 53 J=300,351                                                         WGHT0215
   WTGP3=WTGP3+W(J)                                                        WGHT0216
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   53 CONTINUE                                                        WGHT0217
C              CALC COMMUNICATION AND CONTROL WEIGHTS --GROUP 4       WGHT0218
      W(400)=.000350*V(311)+1.62                                      WGHT0219
      W(401)=5.08E-5*VOLTOT-2.90                                      WGHT0220
      W(403)=.00333*FLDISP+.12                                        WGHT0221
      W(406)=W(486)+W(496)                                            WGHT0222
      W(407)=0.0                                                      WGHT0223
      W(410)=2.0                                                      WGHT0224
      WGP4=0.0                                                        WGHT0225
      WTGP4=0.0                                                       WGHT0226
      DO 54 I=600,699                                                 WGHT0227
      IF(S(I).GT.0.) W(I-200)=S(I)                                    WGHT0228
   54 CONTINUE                                                        WGHT0229
      DO 55 J=400,415                                                 WGHT0230
      WGP4=WGP4+W(J)                                                  WGHT0231
   55 CONTINUE                                                        WGHT0232
      W(450)=.0317*WGP4+.82                                           WGHT0233
      IF(S(650).GT.0.) W(450)=S(650)                                  WGHT0234
      DO 56 K=400,451                                                 WGHT0235
      WTGP4=WTGP4+W(K)                                                WGHT0236
   56 CONTINUE                                                        WGHT0237
C              CALC AUXILIARY SYSTEMS WEIGHTS --GROUP 5               WGHT0238
      W(500)=.000011*VOLTOT+.76                                       WGHT0239
      IF(HTTYP.EQ.2.) W(500)=7.72E-8*VOLTOT**1.443                    WGHT0240
      W(501)=7.28E-5*VOLTOT+4.57                                      WGHT0241
      W(502)=3.46E-5*VOLTOT+4.96                                      WGHT0242
      W(503)=.0205*NACC+3.66                                          WGHT0243
      W(504)=.000728*FLDISP-1.98+W(594)                               WGHT0244
      W(505)=.00107*(V(213)+V(216)+V(219))-.96                        WGHT0245
      W(506)=4.71E-5*VOLTOT+6.63                                      WGHT0246
      W(507)=.000619*VOLTOT**.7224                                    WGHT0247
      W(508)=2.43E-5*VOLHUL+2.15                                      WGHT0248
      W(509)=.00170*V(233)+3.18                                       WGHT0249
      W(510)=.00756*LBP-.75                                           WGHT0250
      GO TO (58,58,58,57,58,58,59,58),PPTYP                           WGHT0251
   57 W(511)=0.0                                                      WGHT0252
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      GO TO 60                                                  WGHT0253
   58 W(511)=.0276*W(816)+4.50                                  WGHT0254
      GO TO 60                                                  WGHT0255
   59 W(511)=.0276*W(817)+4.50                                  WGHT0256
   60 CONTINUE                                                  WGHT0257
      GO TO (61,61,62,62,62,62,62,62),PPTYP                     WGHT0258
   61 W(512)=.00323*W(816)+1.01                                 WGHT0259
      GO TO 63                                                  WGHT0260
   62 W(512)=0.0                                                WGHT0261
   63 CONTINUE                                                  WGHT0262
      GO TO (64,64,66,64,67,67,65,67),PPTYP                     WGHT0263
   64 W(513)=9.59E-5*V(321)-4.50                                WGHT0264
      GO TO 68                                                  WGHT0265
   65 W(513)=.00132*SHP                                         WGHT0266
      GO TO 68                                                  WGHT0267
   66 W(513)=.000426*SHP                                        WGHT0268
      GO TO 68                                                  WGHT0269
   67 W(513)=.000274*SHP+11.78                                  WGHT0270
   68 CONTINUE                                                  WGHT0271
      W(514)=.000012*VOLTOT                                     WGHT0272
      IF(HTTYP.EQ.2.) W(514)=0.0                                WGHT0273
      IF(PPTYP.LE.4) W(514)=.000667*SHP**1.046                  WGHT0274
      W(515)=0.0                                                WGHT0275
      W(516)=0.0                                                WGHT0276
      IF(PPTYP.EQ.4) W(516)=20.0                                WGHT0277
      GO TO (71,71,71,72,73,73,73,73),PPTYP                     WGHT0278
   71 W(517)=9.44E-5*V(321)-.86                                 WGHT0279
      GO TO 70                                                  WGHT0280
   72 W(517)=.0783*NACC**.8847                                  WGHT0281
      GO TO 70                                                  WGHT0282
   73 W(517)=.0172*NACC+2.37                                    WGHT0283
   70 CONTINUE                                                  WGHT0284
      W(518)=6.81E-5*FLDISP*VSUS+3.89                           WGHT0285
      W(519)=.000194*FLDISP*VSUS-.08                            WGHT0286
      W(520)=.00860*FLDISP-2.49                                 WGHT0287
      W(521)=9.14E-6*VOLTOT+.38                                 WGHT0288
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      W(527)=0.0                                                        WGHT0289
      IF(FINST.EQ.2.)  W(527)=.00731*FLDISP-1.20                        WGHT0290
      W(550)=3.5                                                        WGHT0291
      W(551)=4.17E-5*VOLTOT-4.93                                        WGHT0292
      WTGP5=0.0                                                         WGHT0293
      DO 74 I=700,799                                                   WGHT0294
      IF(S(I).GT.0.)  W(I-200)=S(I)                                     WGHT0295
   74 CONTINUE                                                          WGHT0296
      DO 75 J=500,551                                                   WGHT0297
      WTGP5=WTGP5+W(J)                                                  WGHT0298
   75 CONTINUE                                                          WGHT0299
C              CALC OUTFIT AND FURNISHINGS WEIGHTS --GROUP 6            WGHT0300
      W(600)=.00230*FLDISP+3.61                                         WGHT0301
      W(601)=.0971*NACC-1.27                                            WGHT0302
      W(602)=1.0                                                        WGHT0303
      W(603)=.0000403*VOLTOT+6.70                                       WGHT0304
      IF(PPTYP.EQ.4)  W(603)=27.35*FLDISP**.0826                        WGHT0305
      W(604)=.0000321*VOLTOT+3.50                                       WGHT0306
      W(605)=.0000641*VOLTOT+4.26                                       WGHT0307
      W(606)=.0000408*VOLTOT-5.61                                       WGHT0308
      W(607)=(.0000717*VOLHUL+10.56)/C                                  WGHT0309
      W(608)=.0000712*VOLTOT-2.50                                       WGHT0310
      W(609)=.00113*V(224)-.19                                          WGHT0311
      W(610)=.00211*(V(341)+V(342)+V(343))-3.25                         WGHT0312
      W(611)=.0152*NACC+7.37                                            WGHT0313
      W(612)=.000271*(V(211)+V(212)+V(213)+V(214)+V(215)+V(216)+V(217)+ WGHT0314
     1V(218)+V(219))+3.09                                               WGHT0315
      W(613)=.000921*(V(221)+V(313))+1.51                               WGHT0316
      IF(NFLAG.GT.0)  W(613)=.000505*(V(221)+V(313)+V(160))+3.54        WGHT0317
      W(614)=.000265*V(223)+.58                                         WGHT0318
      W(615)=.404*W(703)                                                WGHT0319
      WGP6=0.0                                                          WGHT0320
      WTGP6=0.0                                                         WGHT0321
      DO 76 I=800,899                                                   WGHT0322
      IF(S(I).GT.0.)  W(I-200)=S(I)                                     WGHT0323
   76 CONTINUE                                                          WGHT0324
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      DO 77 J=600,615
      WGP6=WGP6+W(J)
   77 CONTINUE
      WGP6=WGP6+W(651)
      W(650)=.00290*WGP6+.93
      IF(S(850).GT.0.)  W(650)=S(850)
      DO 78 K=600,651
      WTGP6=WTGP6+W(K)
   78 CONTINUE
C               CALC ARMAMENT WEIGHTS --GROUP 7
      W(704)=W(774)+W(784)
      W(720)=0.0
      WGP7=0.0
      WTGP7=0.0
      DO 79 I=900,999
      IF(S(I).GT.0.)  W(I-200)=S(I)
   79 CONTINUE
      DO 80 J=700,712
      WGP7=WGP7+W(J)
   80 CONTINUE
      W(750)=.0101*WGP7+4.66
      IF(S(950).GT.0.)  W(750)=S(950)
      W(751)=.0173*WGP7-.88
      IF(S(951).GT.0.)  W(751)=S(951)
      DO 81 K=700,751
      WTGP7=WTGP7+W(K)
   81 CONTINUE
C               CALC LOADS WEIGHTS --GROUP 8
      W(800)=.0737*NACSC+.105*NOFF+.0737*NCPO+.0290*NCREW+.0737*NFLAG
     1+.0737*NFLAG
      W(801)=.0737*NTRP+.0370*NTRP
      W(802)=.0737*NPASS+.0290*NPASS
      W(803)=W(873)+W(883)+W(893)
      W(806)=.0164*(NACC*DUR)**.8333
      W(807)=.000755*NACC*DUR+1.81
C               REST OF LOADS CALC IN MACHLQ
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      VRLOAD=0.0                                                        WGHT0361
      DO 90 I=1000,1099                                                 WGHT0362
      IF(S(I).GT.0.) W(I-200)=S(I)                                      WGHT0363
   90 CONTINUE                                                          WGHT0364
      DO 91 J=800,822                                                   WGHT0365
      VRLOAD=VRLOAD+W(J)                                                WGHT0366
   91 CONTINUE                                                          WGHT0367
C              CALC LIGHT SHIP WEIGHT                                   WGHT0368
      DISPLS=WTGP1+WTGP2+WTGP3+WTGP4+WTGP5+WTGP6+WTGP7                  WGHT0369
C              CALC WEIGHT MARGIN                                       WGHT0370
      WTMARG=DISPLS*DCMARG                                              WGHT0371
      IF(W(825).GT.0.) WTMARG=W(825)                                    WGHT0372
C              CALC FULL LOAD DISPLACEMENT                              WGHT0373
      DISPFL=DISPLS+VRLOAD+WTMARG                                       WGHT0374
      RETURN                                                            WGHT0375
      END                                                               WGHT0376
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      SUBROUTINE VRTCG                                                  VTCG0001
      REAL LBP,LRD                                                      VTCG0002
      INTEGER PPTYP                                                     VTCG0003
      DIMENSION WVG(900)                                                VTCG0004
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)                       VTCG0005
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY VTCG0006
      COMMON/DEPTH/F0,F10,F20,D0,DMN,D20,H,DECKHT,LRD,DAVG              VTCG0007
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE     VTCG0008
      COMMON/CGS/CG1,CG2,CG3,CG4,CG5,CG6,CG7,CGLDS,CGLSP,CGFLD          VTCG0009
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP   VTCG0010
      COMMON/WTGRPS/WTGP1,WTGP2,WTGP3,WTGP4,WTGP5,WTGP6,WTGP7,VRLOAD,   VTCG0011
     1DISPLS,WTMARG,WBHS,WSS,WDHS,WARM,WFFL,WFG4,WFG5,VOLSHP,WTSHIP     VTCG0012
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400) VTCG0013
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR     VTCG0014
      HLBP=LBP/2.                                                       VTCG0015
      D10=DMN                                                           VTCG0016
      IF(LRD.GE.HLBP) D10=DMN+DECKHT                                    VTCG0017
C              HULL STRUCTURE VCGS                                      VTCG0018
      VCG(100)=.3661*D10+1.45                                           VTCG0019
      VCG(101)=.1999*D10+4.94                                           VTCG0020
      VCG(102)=.1139*D10+.91                                            VTCG0021
      VCG(103)=1.029*H-2.59                                             VTCG0022
      VCG(107)=.8289*D10+3.54                                           VTCG0023
      VCG(111)=1.2334*D10+4.44                                          VTCG0024
      GO TO (3,3,3,1,2,2,3,2),PPTYP                                     VTCG0025
    1 VCG(112)=.2324*H+10.00                                            VTCG0026
      GO TO 5                                                           VTCG0027
    2 VCG(112)=.5784*H                                                  VTCG0028
      GO TO 5                                                           VTCG0029
    3 VCG(112)=.9257*H-8.68                                             VTCG0030
    5 CONTINUE                                                          VTCG0031
      VCG(113)=.2607*H+9.94                                             VTCG0032
      VCG(114)=.6216*D10-2.54                                           VTCG0033
      VCG(115)=.4623*D10+5.27                                           VTCG0034
      VCG(118)=.4529*D10                                                VTCG0035
      VCG(119)=.3055*D10+2.80                                           VTCG0036
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      VCG(120)=.2436*H+1.29                                             VTCG0037
      VCG(122)=.7288*D10                                                VTCG0038
      VCG(123)=.8815*D10-.14                                            VTCG0039
      VCG(125)=.5461*D10+65.75                                          VTCG0040
      VCG(150)=.5829*D10+.68                                            VTCG0041
      VCG(151)=.348*H                                                   VTCG0042
C              PROPULSION VCGS                                          VTCG0043
      VCG(200)=.000271*SHP/NSHFT+4.47                                   VTCG0044
      IF(PPTYP.EQ.4) VCG(200)=.000322*SHP/NSHFT+7.58                    VTCG0045
      VCG(201)=.809*H+1.09                                              VTCG0046
      VCG(202)=.5611*H+.36                                              VTCG0047
      VCG(203)=.6603*H-5.54                                             VTCG0048
      GO TO (6,6,7,6,8,8,6,8),PPTYP                                     VTCG0049
    6 VCG(204)=.000180*SHP/NSHFT+17.45                                  VTCG0050
      GO TO 10                                                          VTCG0051
    7 VCG(204)=.506*D10                                                 VTCG0052
      GO TO 10                                                          VTCG0053
    8 VCG(204)=1.13*D10                                                 VTCG0054
   10 CONTINUE                                                          VTCG0055
      VCG(205)=1.467*D10+9.00                                           VTCG0056
      VCG(206)=.4381*D10+6.23                                           VTCG0057
      VCG(207)=.5178*D10+4.94                                           VTCG0058
      VCG(208)=.2643*D10+5.24                                           VTCG0059
      VCG(209)=.2234*D10+1.21                                           VTCG0060
      VCG(210)=.4219*H+4.12                                             VTCG0061
      VCG(211)=.3492*D10-1.04                                           VTCG0062
      VCG(250)=.1479*D10+11.48                                          VTCG0063
      VCG(251)=.9992*H-4.74                                             VTCG0064
C              ELECTRIC PLANT VCGS                                      VTCG0065
      VCG(300)=.5829*H+7.40                                             VTCG0066
      VCG(301)=.4431*D10+5.89                                           VTCG0067
      VCG(302)=.4432*D10+10.49                                          VTCG0068
      VCG(303)=.8399*D10+1.71                                           VTCG0069
      VCG(350)=.5471*D10-1.63                                           VTCG0070
      VCG(351)=.3542*D10+1.48                                           VTCG0071
C              COMMUNICATION AND CONTROL VCGS                           VTCG0072
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      VCG(400)=1.1534*D10+12.19                                          VTCG0073
      VCG(401)=.7251*D10+3.07                                            VTCG0074
      VCG(403)=.5068*D10+7.04                                            VTCG0075
      VCG(410)=55.0                                                      VTCG0076
      VCG(450)=.2659*D10+19.89                                           VTCG0077
C              AUXILIARY SYSTEMS VCGS                                    VTCG0078
      VCG(500)=.7209*D10+3.08                                            VTCG0079
      IF(HTTYP.EQ.2.) VCG(500)=.3867*D10                                 VTCG0080
      VCG(501)=.7663*D10+7.44                                            VTCG0081
      VCG(502)=.2779*D10+11.11                                           VTCG0082
      VCG(503)=2.4468*H-22.62                                            VTCG0083
      VCG(504)=.8323*D10-7.28                                            VTCG0084
      VCG(505)=.6806*D10+4.26                                            VTCG0085
      VCG(506)=.8267*D10-3.33                                            VTCG0086
      VCG(507)=.7804*D10+.95                                             VTCG0087
      VCG(508)=.1610*D10+4.71                                            VTCG0088
      VCG(509)=.4265*D10+8.39                                            VTCG0089
      VCG(510)=.2834*D10+22.42                                           VTCG0090
      VCG(511)=1.2224*H-6.44                                             VTCG0091
      VCG(512)=.3278*H+.6557                                             VTCG0092
      VCG(513)=16.4                                                      VTCG0093
      VCG(514)=.8126*H+5.53                                              VTCG0094
      IF(PPTYP.GE.5.AND.PPTYP.LE.6) VCG(514)=.7735*H                     VTCG0095
      VCG(516)=.308*D10                                                  VTCG0096
      VCG(517)=.9938*H+1.73                                              VTCG0097
      VCG(518)=1.8139*H-13.10                                            VTCG0098
      VCG(519)=.6428*H+2.40                                              VTCG0099
      VCG(520)=.6252*D10+3.82                                            VTCG0100
      VCG(521)=.8655*D10+8.24                                            VTCG0101
      VCG(527)=.4878*H                                                   VTCG0102
      VCG(550)=.2804*D10+8.53                                            VTCG0103
      VCG(551)=.5007*D10+2.77                                            VTCG0104
C              OUTFIT AND FURNISHINGS VCGS                               VTCG0105
      VCG(600)=.7772*D10+11.86                                           VTCG0106
      VCG(601)=1.0081*D10+10.63                                          VTCG0107
      VCG(602)=1.0183*D10+10.99                                          VTCG0108
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      VCG(603)=.3082*D10+7.18                                           VTCG0109
      VCG(604)=.8684*D10+3.15                                           VTCG0110
      VCG(605)=.4282*D10+7.64                                           VTCG0111
      VCG(606)=.9046*D10-1.03                                           VTCG0112
      VCG(607)=.5420*D10+10.80                                          VTCG0113
      VCG(608)=.4503*D10+7.47                                           VTCG0114
      VCG(609)=.5927*D10+5.92                                           VTCG0115
      VCG(610)=.9440*D10-4.55                                           VTCG0116
      VCG(611)=.8384*D10+2.86                                           VTCG0117
      VCG(612)=.8037*D10+1.75                                           VTCG0118
      VCG(613)=1.0519*D10-.42                                           VTCG0119
      VCG(614)=.4172*D10+15.28                                          VTCG0120
      VCG(615)=VCG(703)                                                 VTCG0121
      VCG(650)=1.1088*D10-13.58                                         VTCG0122
C              ARMAMENT VCGS                                            VTCG0123
      VCG(750)=.546*D10+1.44                                            VTCG0124
      VCG(751)=32.7                                                     VTCG0125
C              LOADS VCGS                                               VTCG0126
      VCG(800)=.7076*D10+1.41                                           VTCG0127
      VCG(801)=VCG(800)                                                 VTCG0128
      VCG(802)=VCG(800)                                                 VTCG0129
      VCG(806)=.5932*D10-2.99                                           VTCG0130
      VCG(807)=.2840*D10+13.54                                          VTCG0131
      VCG(812)=4.2                                                      VTCG0132
      VCG(813)=4.7                                                      VTCG0133
      VCG(814)=1.1519*H-2.20                                            VTCG0134
      VCG(816)=.2515*H+4.27                                             VTCG0135
      VCG(817)=12.5                                                     VTCG0136
      IF(PPTYP.EQ.7) VCG(817)=VCG(816)                                  VTCG0137
C              CALC VCGS OF PAYLOAD ITEMS                               VTCG0138
      DO 11 J=1,900                                                     VTCG0139
   11 WVG(J)=0.0                                                        VTCG0140
      DO 15 I=1,100                                                     VTCG0141
      IF(IT(I).EQ.0) GO TO 15                                           VTCG0142
      IF(P(1,IT(I)).EQ.0.) GO TO 15                                     VTCG0143
      IF(P(5,IT(I))-2.) 12,13,14                                        VTCG0144
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   12 VCG(P(1,IT(I)))=(VCG(P(1,IT(I)))*WVG(P(1,IT(I)))+Q(I)*P(3,IT(I))    VTCG0145
     1*(D10+P(4,IT(I))))/(WVG(P(1,IT(I)))+Q(I)*P(3,IT(I)))                VTCG0146
      WVG(P(1,IT(I)))=WVG(P(1,IT(I)))+Q(I)*P(3,IT(I))                     VTCG0147
      GO TO 15                                                            VTCG0148
   13 VCG(P(1,IT(I)))=(VCG(P(1,IT(I)))*WVG(P(1,IT(I)))+Q(I)*P(3,IT(I))    VTCG0149
     1*P(4,IT(I)))/(WVG(P(1,IT(I)))+Q(I)*P(3,IT(I)))                      VTCG0150
      WVG(P(1,IT(I)))=WVG(P(1,IT(I)))+Q(I)*P(3,IT(I))                     VTCG0151
      GO TO 15                                                            VTCG0152
   14 VCG(P(1,IT(I)))=(VCG(P(1,IT(I)))*WVG(P(1,IT(I)))+Q(I)*P(3,IT(I))    VTCG0153
     1*(D10*P(4,IT(I))))/(WVG(P(1,IT(I)))+Q(I)*P(3,IT(I)))                VTCG0154
      WVG(P(1,IT(I)))=WVG(P(1,IT(I)))+Q(I)*P(3,IT(I))                     VTCG0155
   15 CONTINUE                                                            VTCG0156
C              CALC VCGS OF SPECIAL PAYLOAD ITEMS                         VTCG0157
      DO 16 K=2300,2499,10                                                VTCG0158
      IF(S(K).EQ.0.) GO TO 16                                             VTCG0159
      IF(S(K+4)-2.) 17,18,19                                              VTCG0160
   17 VCG(S(K))=(VCG(S(K))*WVG(S(K))+S(K+2)*(D10+S(K+3)))/(WVG(S(K))+     VTCG0161
     1S(K+2))                                                             VTCG0162
      WVG(S(K))=WVG(S(K))+S(K+2)                                          VTCG0163
      GO TO 16                                                            VTCG0164
   18 VCG(S(K))=(VCG(S(K))*WVG(S(K))+S(K+2)*S(K+3))/(WVG(S(K))+S(K+2))    VTCG0165
      WVG(S(K))=WVG(S(K))+S(K+2)                                          VTCG0166
      GO TO 16                                                            VTCG0167
   19 VCG(S(K))=(VCG(S(K))*WVG(S(K))+S(K+2)*(D10*S(K+3)))/(WVG(S(K))+     VTCG0168
     1S(K+2))                                                             VTCG0169
      WVG(S(K))=WVG(S(K))+S(K+2)                                          VTCG0170
   16 CONTINUE                                                            VTCG0171
C              CHECK FOR VCG DIRECT INPUT                                 VTCG0172
      DO 20 I=1100,1899                                                   VTCG0173
      IF(S(I).GT.0.) VCG(I-1000)=S(I)                                     VTCG0174
   20 CONTINUE                                                            VTCG0175
C              RECALC VCG OF APPROPRIATE PAYLOAD ITEMS                    VTCG0176
      IF(W(406).GT.0.) VCG(406)=(VCG(486)*W(486)+VCG(496)*W(496))/W(406)  VTCG0177
      IF(W(704).GT.0.) VCG(704)=(VCG(774)*W(774)+VCG(784)*W(784))/W(704)  VTCG0178
      IF(W(803).GT.0.) VCG(803)=(VCG(873)*W(873)+VCG(883)*W(883)+         VTCG0179
     1VCG(893)*W(893))/W(803)                                             VTCG0180
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      IF(S(1406).GT.0.) VCG(406)=S(1406)                                VTCG0181
      IF(S(1704).GT.0.) VCG(704)=S(1704)                                VTCG0182
      IF(S(1803).GT.0.) VCG(803)=S(1803)                                VTCG0183
C              NOW CALC MOMENTS                                         VTCG0184
      DO 21 I=1,900                                                     VTCG0185
      VM(I)=W(I)*VCG(I)                                                 VTCG0186
   21 CONTINUE                                                          VTCG0187
C              CALC VCG OF ALL WEIGHT GROUPS                            VTCG0188
      VMGP1=VMGP2=VMGP3=VMGP4=VMGP5=VMGP6=VMGP7=VMLOAD=VMMG=VMLS=VMFL=0.VTCG0189
      DO 22 J=100,151                                                   VTCG0190
      VMGP1=VMGP1+VM(J)                                                 VTCG0191
   22 CONTINUE                                                          VTCG0192
      CG1=VMGP1/WTGP1                                                   VTCG0193
      DO 23 J=200,251                                                   VTCG0194
      VMGP2=VMGP2+VM(J)                                                 VTCG0195
   23 CONTINUE                                                          VTCG0196
      CG2=VMGP2/WTGP2                                                   VTCG0197
      DO 24 J=300,351                                                   VTCG0198
      VMGP3=VMGP3+VM(J)                                                 VTCG0199
   24 CONTINUE                                                          VTCG0200
      CG3=VMGP3/WTGP3                                                   VTCG0201
      DO 25 J=400,451                                                   VTCG0202
      VMGP4=VMGP4+VM(J)                                                 VTCG0203
   25 CONTINUE                                                          VTCG0204
      CG4=VMGP4/WTGP4                                                   VTCG0205
      DO 26 J=500,551                                                   VTCG0206
      VMGP5=VMGP5+VM(J)                                                 VTCG0207
   26 CONTINUE                                                          VTCG0208
      CG5=VMGP5/WTGP5                                                   VTCG0209
      DO 27 J=600,651                                                   VTCG0210
      VMGP6=VMGP6+VM(J)                                                 VTCG0211
   27 CONTINUE                                                          VTCG0212
      CG6=VMGP6/WTGP6                                                   VTCG0213
      DO 28 J=700,751                                                   VTCG0214
      VMGP7=VMGP7+VM(J)                                                 VTCG0215
   28 CONTINUE                                                          VTCG0216
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      CG7=VMGP7/WTGP7                                                   VTCG0217
      DO 29 J=800,822                                                   VTCG0218
      VMLOAD=VMLOAD+VM(J)                                               VTCG0219
   29 CONTINUE                                                          VTCG0220
      CGLDS=VMLOAD/VRLOAD                                               VTCG0221
      VMMG=VCG(825)*W(825)                                              VTCG0222
      VMLS=VMGP1+VMGP2+VMGP3+VMGP4+VMGP5+VMGP6+VMGP7                    VTCG0223
      CGLSP=VMLS/DISPLS                                                 VTCG0224
      VMFL=VMLS+VMLOAD+VMMG                                             VTCG0225
      CGFLD=VMFL/DISPFL                                                 VTCG0226
      RETURN                                                            VTCG0227
      END                                                               VTCG0228
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```
      SUBROUTINE FNCGRP                                                 FGRP0001
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)FGRP0002
      COMMON/VOLUM/V(400),VOLTOT,VOLSST,VOLHUL,VOLMB,FNDEN(400)         FGRP0003
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP   FGRP0004
      COMMON/PEOPLE/NACC,NOFF,NCPO,NCREW,NFLAG,NTRP,NPASS,DUR,NACSC     FGRP0005
      COMMON/WTGRPS/WTGP1,WTGP2,WTGP3,WTGP4,WTGP5,WTGP6,WTGP7,VRLOAD,   FGRP0006
     1DISPLS,WTMARG,WBHS,WSS,WDHS,WARM,WFFL,WFG4,WFG5,VOLSHP,WTSHIP     FGRP0007
C         CALC WEIGHT AND DENSITY ASSOCIATED WITH EACH VOLUME GROUPING  FGRP0008
      VWT(111)=W(409)                                                   FGRP0009
      VWT(112)=W(408)                                                   FGRP0010
      VWT(113)=W(412)                                                   FGRP0011
      VWT(114)=W(404)                                                   FGRP0012
      VWT(115)=W(413)                                                   FGRP0013
      VWT(116)=W(415)+W(450)+W(451)                                     FGRP0014
      DO 1 I=111,116                                                    FGRP0015
      V(110)=V(110)+V(I)                                                FGRP0016
      VWT(110)=VWT(110)+VWT(I)                                          FGRP0017
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0018
    1 CONTINUE                                                          FGRP0019
      VWT(121)=W(402)+W(700)+W(873)                                     FGRP0020
      VWT(122)=W(405)+W(774)+W(883)                                     FGRP0021
      VWT(123)=W(486)+W(784)+W(708)+W(893)                              FGRP0022
      VWT(124)=W(710)                                                   FGRP0023
      VWT(125)=W(711)                                                   FGRP0024
      VWT(126)=W(403)                                                   FGRP0025
      VWT(127)=W(750)+W(751)+W(810)                                     FGRP0026
      VWT(128)=W(703)+W(615)                                            FGRP0027
      DO 2 I=121,128                                                    FGRP0028
      V(120)=V(120)+V(I)                                                FGRP0029
      VWT(120)=VWT(120)+VWT(I)                                          FGRP0030
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0031
    2 CONTINUE                                                          FGRP0032
      WCONT=V(131)/(V(131)+V(221)+V(313))*W(613)                        FGRP0033
      VWT(131)=W(496)+WCONT                                             FGRP0034
      VWT(132)=W(523)+W(524)+W(525)+W(805)                              FGRP0035
      VWT(133)=W(809)+W(811)                                            FGRP0036
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      VWT(134)=W(815)+W(819)
      VWT(135)=W(712)+W(804)
      DO 3 I=131,135
      V(130)=V(130)+V(I)
      VWT(130)=VWT(130)+VWT(I)
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)
    3 CONTINUE
      VWT(140)=W(801)+W(808)
      VWT(150)=W(720)+W(821)
      VWT(160)=.0737*NFLAG*2.
      VWT(170)=W(802)
      VWT(180)=W(529)
      DO 4 I=110,180,10
      V(100)=V(100)+V(I)
      VWT(100)=VWT(100)+VWT(I)
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)
    4 CONTINUE
      IF(V(100).GT.0.) FNDEN(100)=2240.*VWT(100)/V(100)
      WFURN=(V(211)+V(212)+V(214)+V(215)+V(217)+V(218))/(V(211)+V(212)+
     1V(214)+V(215)+V(217)+V(218)+V(225))*W(612)
      VWT(210)=WFURN+.2*W(505)+W(800)-VWT(160)-.04*NOFF-.03*NCPO-.015*
     1NCREW
      DO 5 I=211,219
      V(210)=V(210)+V(I)
    5 CONTINUE
      IF(V(210).GT.0.) FNDEN(210)=2240.*VWT(210)/V(210)
      VWT(221)=V(221)/(V(131)+V(221)+V(313))*W(613)
      VWT(222)=W(611)
      VWT(223)=W(614)
      VWT(224)=W(609)
      VWT(225)=W(612)-WFURN
      VWT(226)=W(594)
      DO 6 I=221,226
      V(220)=V(220)+V(I)
      VWT(220)=VWT(220)+VWT(I)
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)
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    6 CONTINUE                                                          FGRP0073
      IF(V(220).GT.0.) FNDEN(220)=2240.*VWT(220)/V(220)                 FGRP0074
      VWT(231)=W(806)                                                   FGRP0075
      VWT(232)=(1./3.)*W(608)+.04*NOFF+.03*NCPO+.015*NCREW              FGRP0076
      VWT(233)=W(812)                                                   FGRP0077
      DO 7 I=231,233                                                    FGRP0078
      V(230)=V(230)+V(I)                                                FGRP0079
      VWT(230)=VWT(230)+VWT(I)                                          FGRP0080
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0081
    7 CONTINUE                                                          FGRP0082
      IF(V(230).GT.0.) FNDEN(230)=2240.*VWT(230)/V(230)                 FGRP0083
      DO 8 I=210,230,10                                                 FGRP0084
      V(200)=V(200)+V(I)                                                FGRP0085
      VWT(200)=VWT(200)+VWT(I)                                          FGRP0086
    8 CONTINUE                                                          FGRP0087
      IF(V(200).GT.0.) FNDEN(200)=2240.*VWT(200)/V(200)                 FGRP0088
      VWT(311)=W(400)+W(401)+W(410)+W(411)                              FGRP0089
      VWT(313)=V(313)/(V(131)+V(221)+V(313))*W(613)                     FGRP0090
      DO 9 I=311,313                                                    FGRP0091
      V(310)=V(310)+V(I)                                                FGRP0092
      VWT(310)=VWT(310)+VWT(I)                                          FGRP0093
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0094
    9 CONTINUE                                                          FGRP0095
      VWT(321)=W(200)+W(201)+W(202)+W(204)+W(206)+W(207)+W(208)+W(209)  FGRP0096
     1+W(210)+W(211)+W(251)+W(300)+W(301)+W(351)+W(502)+W(503)+W(504)   FGRP0097
     2-W(594)+W(512)+W(513)+W(514)+W(517)+W(527)+W(551)+(2./3.)*W(603)  FGRP0098
      VWT(322)=W(205)                                                   FGRP0099
      VWT(323)=W(203)                                                   FGRP0100
      VWT(324)=W(518)+W(519)                                            FGRP0101
      VWT(325)=W(501)*.8                                                FGRP0102
      DO 10 I=321,325                                                   FGRP0103
      V(320)=V(320)+V(I)                                                FGRP0104
      VWT(320)=VWT(320)+VWT(I)                                          FGRP0105
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0106
   10 CONTINUE                                                          FGRP0107
      VWT(331)=W(520)+W(600)                                            FGRP0108
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      VWT(332)=W(528)                                                   FGRP0109
      V(330)=V(331)+V(332)                                              FGRP0110
      VWT(330)=VWT(331)+VWT(332)                                        FGRP0111
      DO 11 I=331,332                                                   FGRP0112
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0113
   11 CONTINUE                                                          FGRP0114
      VWT(341)=V(341)/(V(341)+V(342)+V(343))*W(610)                     FGRP0115
      VWT(342)=V(342)/(V(341)+V(342)+V(343))*W(610)                     FGRP0116
      VWT(343)=V(343)/(V(341)+V(342)+V(343))*W(610)+W(602)+W(605)       FGRP0117
      DO 12 I=341,343                                                   FGRP0118
      V(340)=V(340)+V(I)                                                FGRP0119
      VWT(340)=VWT(340)+VWT(I)                                          FGRP0120
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0121
   12 CONTINUE                                                          FGRP0122
      VWT(351)=W(816)                                                   FGRP0123
      VWT(352)=W(813)                                                   FGRP0124
      VWT(353)=W(814)                                                   FGRP0125
      VWT(354)=W(817)                                                   FGRP0126
      VWT(355)=W(818)+W(820)                                            FGRP0127
      VWT(356)=(2./3.)*W(608)+W(250)+W(350)+W(550)+W(650)+W(807)        FGRP0128
      VWT(357)=W(601)                                                   FGRP0129
      DO 13 I=351,357                                                   FGRP0130
      V(350)=V(350)+V(I)                                                FGRP0131
      VWT(350)=VWT(350)+VWT(I)                                          FGRP0132
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0133
   13 CONTINUE                                                          FGRP0134
      VWT(361)=W(822)                                                   FGRP0135
      DO 14 I=361,365                                                   FGRP0136
      V(360)=V(360)+V(I)                                                FGRP0137
      VWT(360)=VWT(360)+VWT(I)                                          FGRP0138
      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                         FGRP0139
   14 CONTINUE                                                          FGRP0140
      VWT(370)=(1./3.)*W(603)                                           FGRP0141
      DO 15 I=310,390,10                                                FGRP0142
      V(300)=V(300)+V(I)                                                FGRP0143
      VWT(300)=VWT(300)+VWT(I)                                          FGRP0144
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      IF(V(I).GT.0.) FNDEN(I)=2240.*VWT(I)/V(I)                          FGRP0145
   15 CONTINUE                                                           FGRP0146
      IF(V(300).GT.0.) FNDEN(300)=2240.*VWT(300)/V(300)                  FGRP0147
      WBHS=W(100)+W(101)+W(107)*.5+.7*W(150)                             FGRP0148
      WSS=W(102)+W(103)+W(112)+W(114)+W(115)+W(118)+W(119)+W(120)+W(121) FGRP0149
     1+W(122)+W(123)+W(125)+W(127)+W(128)+.3*W(150)+W(510)+W(604)+W(113) FGRP0150
     2+W(116)+W(107)*.5                                                  FGRP0151
      WDHS=W(111)                                                        FGRP0152
      WARM=W(117)                                                        FGRP0153
      WFFL=W(151)                                                        FGRP0154
      WFG4=WBHS+WSS+WDHS+WARM+WFFL                                       FGRP0155
      WFG5=W(302)+W(303)+W(500)+W(506)+W(507)+.2*W(501)+W(508)+W(511)+   FGRP0156
     1W(516)+W(521)+W(522)+W(526)+W(606)+W(607)+W(651)+WTMARG+W(509)     FGRP0157
     2+.8*W(505)                                                         FGRP0158
      VOLSHP=V(100)+V(200)+V(300)                                        FGRP0159
      WTSHIP=VWT(100)+VWT(200)+VWT(300)+WFG4+WFG5                        FGRP0160
      RETURN                                                             FGRP0161
      END                                                                FGRP0162
```

```
      SUBROUTINE SEASPD(AVSP)
      INTEGER PPTYP
      REAL LEN,KGTRY,KY,IY,JY,KYY,LBP,LBRAT,LRD
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY
      COMMON/DEPTH/F0,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG
      KY=.24
      G=32.155
      R=1.9905
      LEN=LBP
      PI=3.14159
      IY=(KY*LEN)**2*2240.*DPTRY/G
      CIL=.14210526*CWP-.063568
      JY=CIL*B*LEN**3
      C=H
      B1=B/2.
      A=LEN/2.
      BCC=B1/C+1.19-(1.64-.86666697E-1*A/B1+.625E-2*(A/B1)**2-.20833346E
     1-3*(A/B1)**3)
      YYK1=.66302837E-1+.5773045*BCC+.31592344*BCC**2-.15287906*BCC**3
     1+.028399747*BCC**4
      IF(CX-.814)1,2,3
    3 CXP=(CX-.814)*.81395
      CXH=(CX-.814)*.60465
      GO TO 4
    2 CXP=0.
      CXH=0.
      GO TO 4
    1 CXP=0.
      CXH=(CX-.814)*.27193
    4 FKYY=.6051
      CPP=(CP-.58)*2.76666
      CSP=FKYY+CPP+CXP
      IYY=YYK1*CSP/120.*PI*R*LEN*B*H*(LEN*LEN+4.*H*H)
      TP=2.*PI*((IY+IYY)/(G*R*JY))**.5
      ZK1=1.9+(B1/C-2.)/1.05
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      FKZ=.599                                                          SEAS0037
      CPH=(CP-.58)*1.41666                                              SEAS0038
      CSH=FKZ+CPH+CXH                                                   SEAS0039
      SM=2240.*DPTRY/G                                                  SEAS0040
      AWP=CWP*LEN*B                                                     SEAS0041
      ZM=CSH*ZK1*PI*R*LEN*B*H/6.                                        SEAS0042
      TH=6.28318*SQRT((SM+ZM)/(G*R*AWP))                                SEAS0043
      TPL=TP/(SQRT(LEN))                                                SEAS0044
      THL=TH/(SQRT(LEN))                                                SEAS0045
      T=TPL                                                             SEAS0046
      IF(THL.GT.TPL) T=THL                                              SEAS0047
      VLR=(.9025/T-SQRT(.95*G/(2.*PI)))/1.6878                          SEAS0048
      WAVEH=.0256465*LEN                                                SEAS0049
      W=DPTRY/(100.*(.01*LEN)**3)                                       SEAS0050
      WW=(11.*W*W-8.25281*W+3.86439)/6000.                              SEAS0051
      VRT=16.*H/LEN+.60293*W-.15617+WW*LEN                              SEAS0052
      VLR=VRT*VLR                                                       SEAS0053
      SPEED=VLR*SQRT(LEN)                                               SEAS0054
      IF(SPEED.LT.VSUS) GO TO 6                                         SEAS0055
      PER1=100.                                                         SEAS0056
      GO TO 5                                                           SEAS0057
    6 IF(WAVEH.LT.8.) GO TO 7                                           SEAS0058
      IF(WAVEH.LT.13.) GO TO 8                                          SEAS0059
      PER1=-40.49996+14.949994*WAVEH-.54333305*WAVEH**2+.66666623E-2*   SEAS0060
     1WAVEH**3                                                          SEAS0061
      GO TO 5                                                           SEAS0062
    8 PER1=-126.00002+21.933338*WAVEH-.25625043*WAVEH**2-.017708321*    SEAS0063
     1WAVEH**3                                                          SEAS0064
      GO TO 5                                                           SEAS0065
    7 PER1=-.89785317E-7+.14285863*WAVEH-.13333482*WAVEH**2+.037500399* SEAS0066
     1WAVEH**3+.29761609E-2*WAVEH**4                                    SEAS0067
    5 PER2=(100.-PER1)/2.                                               SEAS0068
      PER=100.-PER2                                                     SEAS0069
      AVSP=(PER*VSUS+PER2*SPEED)/100.                                   SEAS0070
      RETURN                                                            SEAS0071
      END                                                               SEAS0072
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```
      SUBROUTINE OUTPUT
      REAL LBP,KGTRY,LRD,LBRAT
      REAL*8 NS(100),NTYP(50),NSR(70),NCOMP(400),NWT(830),NELC(20)
      INTEGER PPTYP,SSETYP,EMETYP
      DIMENSION SR(70)
      COMMON/VALUES/NS,NTYP,NSR,NCOMP,NWT,NELC
      COMMON/OUT/PRTOUT,AVSP,EXCKG,ICONST,NSHIP
      COMMON/PROPPW/VSUS,VEND,DELCF,PPTYP,JHPOPT,PCMXSP,PCEND,ENDUR
      COMMON/GENSZ/KWSSER,KWEMER,KWINST,SSETYP,EMETYP,NLSD,NMSD,NHSD,
     1NGTG,NSTG,KWPRD,KWPRGT,KWPRSG,NGFCLD,NGAVG,NSSG,NEMG,KELEC
      COMMON/MNMACH/SHP,NB,NR,NE,NSHFT,PRPTYP,SHFTYP,RPM,DPROP,SHPE
      COMMON/MISC/FINST,HULMAT,SSMAT,PASTYP
      COMMON/ELPLT/ECR(11),EBT(11),EAV(11),ELMARG,MXFCKW,KW24AV,HTTYP
      COMMON/DATA/P(7,300),S(2500),Q(100),IT(100)
      COMMON/UND/FSCORR,CP,CX,GMBMIN,KGTRY,B,CWP,LBP,R,LBRAT,BHRAT,DPTRY
      COMMON/DEPTH/FO,F10,F20,D0,D10,D20,H,DECKHT,LRD,DAVG
      COMMON/CGS/CG1,CG2,CG3,CG4,CG5,CG6,CG7,CGLDS,CGLSP,CGFLD
      COMMON/PEOPLE/NACC,NOFF,NCPO,NCREW,NFLAG,NTRP,NPASS,DUR,NACSC
      COMMON/WTMOM/W(900),VM(900),VCG(900),WPAYIN,DCMARG,DISPFL,VWT(400)
      COMMON/WTGRPS/WTGP1,WTGP2,WTGP3,WTGP4,WTGP5,WTGP6,WTGP7,VRLOAD,
     1DISPLS,WTMARG,WBHS,WSS,WDHS,WARM,WFFL,WFG4,WFG5,VOLSHP,WTSHIP
      COMMON/VOLUM/V(400),VOLTOT,VOLSST,VOLHUL,VOLMB,FNDEN(400)
C         PRINT THE SPECIFICATIONS
      IF(PPTYP.EQ.1) NTYP(1)=NTYP(16)
      IF(PPTYP.EQ.2)  NTYP(1)=NTYP(17)
      IF(PPTYP.EQ.3)  NTYP(1)=NTYP(18)
      IF(PPTYP.EQ.4)  NTYP(1)=NTYP(19)
      IF(PPTYP.EQ.5)  NTYP(1)=NTYP(20)
      IF(PPTYP.EQ.6)  NTYP(1)=NTYP(21)
      IF(PPTYP.EQ.7)  NTYP(1)=NTYP(22)
      IF(PPTYP.EQ.8)  NTYP(1)=NTYP(23)
      IF(SSETYP.EQ.1) NTYP(2)=NTYP(24)
      IF(SSETYP.EQ.2) NTYP(2)=NTYP(25)
      IF(SSETYP.EQ.3) NTYP(2)=NTYP(26)
      IF(SSETYP.EQ.4) NTYP(2)=NTYP(27)
      IF(SSETYP.EQ.5) NTYP(2)=NTYP(28)
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      IF(SSETYP.EQ.6) NTYP(2)=NTYP(29)
      IF(EMETYP.EQ.1) NTYP(3)=NTYP(25)
      IF(EMETYP.EQ.2) NTYP(3)=NTYP(26)
      IF(EMETYP.EQ.3) NTYP(3)=NTYP(27)
      IF(EMETYP.EQ.4) NTYP(3)=NTYP(28)
      IF(EMETYP.EQ.5) NTYP(3)=NTYP(29)
      IF(SHFTYP.EQ.1.) NTYP(6)=NTYP(30)
      IF(SHFTYP.EQ.2.) NTYP(6)=NTYP(31)
      IF(PRPTYP.EQ.1.) NTYP(7)=NTYP(32)
      IF(PRPTYP.EQ.2.) NTYP(7)=NTYP(33)
      IF(FINST.EQ.1.) NTYP(8)=NTYP(34)
      IF(FINST.EQ.2.) NTYP(8)=NTYP(35)
      IF(HTTYP.EQ.1.) NTYP(9)=NTYP(36)
      IF(HTTYP.EQ.2.) NTYP(9)=NTYP(37)
      IF(HULMAT.EQ.1.) NTYP(11)=NTYP(38)
      IF(HULMAT.EQ.2.) NTYP(11)=NTYP(39)
      IF(SSMAT.EQ.1.) NTYP(12)=NTYP(38)
      IF(SSMAT.EQ.2.) NTYP(12)=NTYP(39)
      IF(PASTYP.EQ.1.) NTYP(13)=NTYP(40)
      IF(PASTYP.EQ.2.) NTYP(13)=NTYP(41)
      PRINT 7,NSHIP
    7 FORMAT(1H1,10X,'SHIP NUMBER',I4)
      PRINT 11
   11 FORMAT(1H0,32X,'SHIP SPECIFICATIONS'/)
      S(26)=S(26)*10000.0
      DO 12 J=1,25
   12 PRINT 13,NS(J),S(J),NS(J+25),S(J+25),NS(J+50),S(J+50)
   13 FORMAT(1H ,10X,3(A8,F10.2,3X))
      S(26)=S(26)/10000.0
      PRINT 9
    9 FORMAT(1H )
      DO 14 J=1,5
   14 PRINT 15,NS(J+75),NTYP(J),NS(J+80),NTYP(J+5),NS(J+85),NTYP(J+10)
   15 FORMAT(1H ,10X,3(A8,3X,A8,2X))
C          PRINT THE SPECIAL PAYLOAD INPUT
      SPEC=0.
```

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      PRINT 16                                                          OUTP0073
   16 FORMAT(1H0,32X,'SPECIAL PAYLOAD INPUT'//1H ,10X,'WT GRP',4X,      OUTP0074
     1'VOL GRP',4X,'WT',4X,'VCG NU',4X,'VCG REF',4X,'AREA SUP',4X,      OUTP0075
     2'AREA HULL'/)                                                     OUTP0076
      DO 17 J=2300,2499,10                                              OUTP0077
      IF(S(J).EQ.0..AND.S(J+1).EQ.0.) GO TO 17                          OUTP0078
      PRINT 20,S(J),S(J+1),S(J+2),S(J+3),S(J+4),S(J+5),S(J+6)           OUTP0079
   20 FORMAT(1H ,10X,F5.0,6X,F5.0,2X,F7.1,3X,F5.1,5X,F3.0,7X,F7.1,6X,   OUTP0080
     1F7.1)                                                             OUTP0081
      SPEC=1.0                                                          OUTP0082
   17 CONTINUE                                                          OUTP0083
      IF(SPEC.EQ.1.) GO TO 21                                           OUTP0084
      PRINT 22                                                          OUTP0085
   22 FORMAT(1H ,10X,'NO SPECIAL PAYLOAD INPUT')                        OUTP0086
   21 CONTINUE                                                          OUTP0087
      PRINT 7,NSHIP                                                     OUTP0088
C                PRINT THE PAYLOAD SPECIFICATIONS                       OUTP0089
      PRINT 400                                                         OUTP0090
  400 FORMAT(1H0,30X,'PAYLOAD SPECIFICATIONS'//13X,5('QNTY',1X,'ITEM',  OUTP0091
     14X)/)                                                             OUTP0092
      DO 455 K=1,20                                                     OUTP0093
  405 IF(Q(K).LE.0) GO TO 415                                           OUTP0094
      PRINT 410,Q(K),IT(K)                                              OUTP0095
  410 FORMAT(1H+,9X,F8.2,1X,I3)                                         OUTP0096
  415 IF(Q(K+20).LE.0) GO TO 425                                        OUTP0097
      PRINT 420,Q(K+20),IT(K+20)                                        OUTP0098
  420 FORMAT(1H+,22X,F8.2,1X,I3)                                        OUTP0099
  425 IF(Q(K+40).LE.0) GO TO 435                                        OUTP0100
      PRINT 430,Q(K+40),IT(K+40)                                        OUTP0101
  430 FORMAT(1H+,35X,F8.2,1X,I3)                                        OUTP0102
  435 IF(Q(K+60).LE.0) GO TO 445                                        OUTP0103
      PRINT 440,Q(K+60),IT(K+60)                                        OUTP0104
  440 FORMAT(1H+,48X,F8.2,1X,I3)                                        OUTP0105
  445 IF(Q(K+80).LE.0) GO TO 455                                        OUTP0106
      PRINT 450,Q(K+80),IT(K+80)                                        OUTP0107
  450 FORMAT(1H+,61X,F8.2,1X,I3)                                        OUTP0108
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  455 PRINT 9                                                           OUTP0109
C         SET DATA FOR RESULTS                                          OUTP0110
      SR(1)=LBP                                                         OUTP0111
      SR(2)=B                                                           OUTP0112
      SR(3)=H                                                           OUTP0113
      SR(4)=D0                                                          OUTP0114
      SR(5)=D10                                                         OUTP0115
      SR(6)=D20                                                         OUTP0116
      SR(7)=DAVG+LRD/LBP*DECKHT                                         OUTP0117
      SR(8)=LRD                                                         OUTP0118
      SR(9)=CP                                                          OUTP0119
      SR(10)=CX                                                         OUTP0120
      SR(11)=CGFLD                                                      OUTP0121
      SR(12)=CGFLD/DAVG                                                 OUTP0122
      SR(13)=LBP/B                                                      OUTP0123
      SR(14)=B/H                                                        OUTP0124
      SR(15)=EXCKG                                                      OUTP0125
      SR(16)=ENDUR                                                      OUTP0126
      SR(17)=SHP                                                        OUTP0127
      SR(18)=SHPE                                                       OUTP0128
      SR(19)=VSUS                                                       OUTP0129
      SR(20)=VEND                                                       OUTP0130
      SR(21)=AVSP                                                       OUTP0131
      SR(22)=NACC                                                       OUTP0132
      SR(23)=KWINST                                                     OUTP0133
      SR(24)=KWSSER                                                     OUTP0134
      SR(25)=KWEMER                                                     OUTP0135
      SR(26)=DISPFL                                                     OUTP0136
      SR(27)=DISPLS                                                     OUTP0137
      SR(28)=VRLOAD                                                     OUTP0138
      SR(29)=WTMARG                                                     OUTP0139
      SR(3C)=WTGP1                                                      OUTP0140
      SR(31)=WTGP2                                                      OUTP0141
      SR(32)=WTGP3                                                      OUTP0142
      SR(33)=WTGP4                                                      OUTP0143
      SR(34)=WTGP5                                                      OUTP0144
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      SR(35)=WTGP6                                                      OUTP0145
      SR(36)=WTGP7                                                      OUTP0146
      SR(37)=VOLTOT                                                     OUTP0147
      SR(38)=VOLHUL                                                     OUTP0148
      SR(39)=VOLSST                                                     OUTP0149
      SR(40)=ECR(11)                                                    OUTP0150
      SR(41)=EBT(11)                                                    OUTP0151
      SR(42)=EAV(11)                                                    OUTP0152
      SR(43)=NLSD                                                       OUTP0153
      SR(44)=NMSD                                                       OUTP0154
      SR(45)=NHSD                                                       OUTP0155
      SR(46)=NGTG                                                       OUTP0156
      SR(47)=NSTG                                                       OUTP0157
      SR(48)=KWPRD                                                      OUTP0158
      SR(49)=KWPRGT                                                     OUTP0159
      SR(50)=KWPRSG                                                     OUTP0160
      SR(51)=DISPFL*2240./VOLTOT                                        OUTP0161
      SR(52)=DISPLS*2240./VOLTOT                                        OUTP0162
      SR(53)=VWT(100)/WTSHIP                                            OUTP0163
      SR(54)=VWT(200)/WTSHIP                                            OUTP0164
      SR(55)=VWT(300)/WTSHIP                                            OUTP0165
      SR(56)=V(100)/VOLSHP                                              OUTP0166
      SR(57)=V(200)/VOLSHP                                              OUTP0167
      SR(58)=V(300)/VOLSHP                                              OUTP0168
      SR(59)=WTGP2*2240./SHP                                            OUTP0169
      SR(60)=V(321)/SHP                                                 OUTP0170
      SR(61)=WTGP3*2240./KWINST                                         OUTP0171
      SR(62)=WTGP1*2240./VOLTOT                                         OUTP0172
      SR(63)=WTGP5*2240./VOLTOT                                         OUTP0173
      SR(64)=(V(200)-V(230))/NACC                                       OUTP0174
      SR(65)=(VWT(200)-VWT(230))*2240./NACC                             OUTP0175
      SR(66)=NACC/DISPFL                                                OUTP0176
      SR(67)=KWINST/DISPFL                                              OUTP0177
      SR(68)=SHP/DISPFL                                                 OUTP0178
      SR(69)=6.88*DISPFL*VSUS/SHP                                       OUTP0179
      SR(70)=VWT(100)*VSUS/DISPFL                                       OUTP0180
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C          PRINT SUMMARY OF RESULTS                                         OUTP0181
      PRINT 31                                                              OUTP0182
   31 FORMAT(1H0,32X,'SUMMARY OF RESULTS'/)                                 OUTP0183
      DO 32 J=1,20                                                          OUTP0184
   32 PRINT 33,NSR(J),SR(J),NSR(J+25),SR(J+25),NSR(J+50),SR(J+50)           OUTP0185
   33 FORMAT(1H ,10X,3(A8,F10.2,3X))                                        OUTP0186
      DO 34 J=21,25                                                         OUTP0187
   34 PRINT 35,NSR(J),SR(J),NSR(J+25),SR(J+25)                              OUTP0188
   35 FORMAT(1H ,10X,2(A8,F10.2,3X))                                        OUTP0189
C          PRINT THE CONSTANTS                                              OUTP0190
      IF(ICONST.NE.1) GO TO 41                                              OUTP0191
      PRINT 7,NSHIP                                                         OUTP0192
      PRINT 42                                                              OUTP0193
   42 FORMAT(1H0,15X,'SHIP CONSTANTS'//1H ,10X,'ELEMENT NUMBER',5X,         OUTP0194
     1'VALUE'/)                                                             OUTP0195
      DO 43 J=2250,2299                                                     OUTP0196
   43 PRINT 44,J,S(J)                                                       OUTP0197
   44 FORMAT(1H ,15X,I5,9X,F5.2)                                            OUTP0198
   41 CONTINUE                                                              OUTP0199
C          PRINT DETAILED FUNCTIONAL GROUPING                               OUTP0200
      IF(PRTOUT.LT.1.) GO TO 200                                            OUTP0201
      PRINT 7,NSHIP                                                         OUTP0202
      PRINT 40                                                              OUTP0203
   40 FORMAT(1H0,25X,'DETAILED RESULTS--FUNCTIONAL GROUPING')               OUTP0204
      PRINT 45                                                              OUTP0205
   45 FORMAT(1H0,10X,'GROUP',4X,'NAME',4X,'WEIGHT',4X,'WT FRAC',4X,         OUTP0206
     1'VOLUME',4X,'VOL FRAC',5X,'DENSITY'/1H ,28X,'TONS',17X,'CU FT',       OUTP0207
     216X,'LBS/CU FT')                                                      OUTP0208
      PRINT 46,NCOMP(100),VWT(100),VWT(100)/WTSHIP,V(100),V(100)/VOLSHP,    OUTP0209
     1FNDEN(100)                                                            OUTP0210
   46 FORMAT(1H0,10X,'100',4X,A8,F8.1,4X,F6.4,3X,F8.0,4X,F6.4,6X,F7.2/)     OUTP0211
      DO 47 I=110,116                                                       OUTP0212
   47 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)    OUTP0213
   48 FORMAT(1H ,10X,I3,4X,A8,F8.1,4X,F6.4,3X,F8.0,4X,F6.4,6X,F7.2)         OUTP0214
      PRINT 9                                                               OUTP0215
      DO 49 I=120,128                                                       OUTP0216
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49 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0217
   PRINT 9                                                                    OUTP0218
   DO 50 I=130,135                                                            OUTP0219
50 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0220
   PRINT 9                                                                    OUTP0221
   DO 51 I=140,180,10                                                         OUTP0222
51 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0223
   PRINT 9                                                                    OUTP0224
   PRINT 52,NCOMP(200),VWT(200),VWT(200)/WTSHIP,V(200),V(200)/VOLSHP,          OUTP0225
  1FNDEN(200)                                                                 OUTP0226
52 FORMAT(1H0,10X,'200',4X,A8,F8.1,4X,F6.4,3X,F8.0,4X,F6.4,6X,F7.2/)           OUTP0227
   DO 53 I=210,219                                                            OUTP0228
53 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0229
   PRINT 7,NSHIP                                                              OUTP0230
   PRINT 54                                                                   OUTP0231
54 FORMAT(1H0,25X,'DETAILED RESULTS--FUNCTIONAL GROUPING CONTINUED')           OUTP0232
   PRINT 45                                                                   OUTP0233
   PRINT 9                                                                    OUTP0234
   DO 55 I=220,226                                                            OUTP0235
55 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0236
   PRINT 9                                                                    OUTP0237
   DO 56 I=230,233                                                            OUTP0238
56 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0239
   PRINT 9                                                                    OUTP0240
   PRINT 57,NCOMP(300),VWT(300),VWT(300)/WTSHIP,V(300),V(300)/VOLSHP,          OUTP0241
  1FNDEN(300)                                                                 OUTP0242
57 FORMAT(1H0,10X,'300',4X,A8,F8.1,4X,F6.4,3X,F8.0,4X,F6.4,6X,F7.2/)           OUTP0243
   DO 58 I=310,313                                                            OUTP0244
58 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0245
   PRINT 9                                                                    OUTP0246
   DO 59 I=320,325                                                            OUTP0247
59 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0248
   PRINT 9                                                                    OUTP0249
   DO 60 I=330,332                                                            OUTP0250
60 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)          OUTP0251
   PRINT 9                                                                    OUTP0252
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      DO 61 I=340,343
   61 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)
      PRINT 9
      DO 62 I=350,357
   62 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)
      PRINT 7,NSHIP
      PRINT 54
      PRINT 45
      PRINT 9
      DO 63 I=360,365
   63 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)
      PRINT 9
      DO 64 I=370,390,10
   64 PRINT 48,I,NCOMP(I),VWT(I),VWT(I)/WTSHIP,V(I),V(I)/VOLSHP,FNDEN(I)
      PRINT 65,WFG4,WFG4/WTSHIP,WBHS,WBHS/WTSHIP,WSS,WSS/WTSHIP,WDHS,
     1WDHS/WTSHIP,WARM,WARM/WTSHIP,WFFL,WFFL/WTSHIP,WFG5,WFG5/WTSHIP
   65 FORMAT(1H0,10X,'400',4X,'HULL GRP',F8.1,4X,F6.4/1H0,10X,'410',4X,
     1'BASCHULL',F8.1,4X,F6.4/1H ,10X,'420',4X,'SEC HULL',F8.1,4X,F6.4/
     21H ,10X,'430',4X,'DECKHOUS',F8.1,4X,F6.4/1H ,10X,'440',4X,'ARMOR',
     33X,F8.1,4X,F6.4/1H ,10X,'450',4X,'FREEFLLQ',F8.1,4X,F6.4/1H0,10X,
     4'500',4X,'SHIP SYS',F8.1,4X,F6.4/)
      PRINT 66,WTSHIP,WTSHIP/WTSHIP,VOLSHP,VOLSHP/VOLSHP,
     12240.*WTSHIP/VOLSHP
   66 FORMAT(1H0,17X,'TOTAL',3X,F8.1,4X,F6.4,3X,F8.0,4X,F6.4,6X,F7.2)
C           PRINT DETAILED BSCI WT LISTING
      IF(PRTOUT.LT.2.) GO TO 200
      PRINT 7,NSHIP
      PRINT 67
   67 FORMAT(1H0,17X,'DETAILED RESULTS--BSCI WEIGHT LISTING')
      PRINT 68
   68 FORMAT(1H0,10X,'GROUP',4X,'NAME',4X,'WEIGHT',4X,
     1'WT FRAC',4X,'WT FRAC',4X,'VCG'/1H ,28X,'TONS',5X,'FULL LD',4X,
     2'LITE SH',5X,'FT'/)
      DO 69 I=100,125
   69 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
   70 FORMAT(1H ,10X,I3,4X,A8,F8.1,4X,F6.4,5X,F6.4,4X,F5.1)
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      DO 71 I=127,128
   71 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      DO 72 I=150,151
   72 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      PRINT 73,WTGP1,WTGP1/DISPFL,WTGP1/DISPLS,CG1
   73 FORMAT(1H ,17X,'GRP1 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)
      DO 74 I=200,211
   74 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      DO 75 I=250,251
   75 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      PRINT 76,WTGP2,WTGP2/DISPFL,WTGP2/DISPLS,CG2
   76 FORMAT(1H ,17X,'GRP2 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)
      PRINT 7,NSHIP
      PRINT 77
   77 FORMAT(1H0,17X,'DETAILED RESULTS--BSCI WEIGHT LISTING CONTINUED')
      PRINT 68
      DO 78 I=300,303
   78 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      DO 79 I=350,351
   79 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      PRINT 80,WTGP3,WTGP3/DISPFL,WTGP3/DISPLS,CG3
   80 FORMAT(1H ,17X,'GRP3 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)
      DO 81 I=400,413
   81 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      I=415
      PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      DO 82 I=450,451
   82 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      PRINT 83,WTGP4,WTGP4/DISPFL,WTGP4/DISPLS,CG4
   83 FORMAT(1H ,17X,'GRP4 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)
      DO 84 I=500,520
   84 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)
      PRINT 7,NSHIP
      PRINT 77
      PRINT 68
      DO 85 I=521,528
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85 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0325
   DO 86 I=550,551                                                      OUTP0326
86 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0327
   PRINT 87,WTGP5,WTGP5/DISPFL,WTGP5/DISPLS,CG5                         OUTP0328
87 FORMAT(1H ,17X,'GRP5 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)             OUTP0329
   DO 88 I=600,615                                                      OUTP0330
88 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0331
   DO 89 I=650,651                                                      OUTP0332
89 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0333
   PRINT 90,WTGP6,WTGP6/DISPFL,WTGP6/DISPLS,CG6                         OUTP0334
90 FORMAT(1H ,17X,'GRP6 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)             OUTP0335
   DO 91 I=700,713                                                      OUTP0336
91 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0337
   I=720                                                                OUTP0338
   PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0339
   DO 92 I=750,751                                                      OUTP0340
92 PRINT 70,I,NWT(I),W(I),W(I)/DISPFL,W(I)/DISPLS,VCG(I)                OUTP0341
   PRINT 93,WTGP7,WTGP7/DISPFL,WTGP7/DISPLS,CG7                         OUTP0342
93 FORMAT(1H ,17X,'GRP7 TOT',F8.1,4X,F6.4,5X,F6.4,4X,F5.1/)             OUTP0343
   PRINT 7,NSHIP                                                        OUTP0344
   PRINT 77                                                             OUTP0345
   PRINT 94                                                             OUTP0346
94 FORMAT(1H0,10X,'GROUP',4X,'NAME',4X,'WEIGHT',4X,'WT FRAC',4X,        OUTP0347
  1'VCG'/1H ,28X,'TONS',5X,'FULL LD',5X,'FT'/)                          OUTP0348
   DO 95 I=800,822                                                      OUTP0349
95 PRINT 96,I,NWT(I),W(I),W(I)/DISPFL,VCG(I)                            OUTP0350
96 FORMAT(1H ,10X,I3,4X,A8,F8.1,4X,F6.4,4X,F5.1)                        OUTP0351
   PRINT 97,VRLOAD,VRLOAD/DISPFL,CGLDS,DISPLS,DISPLS/DISPFL,CGLSP,      OUTP0352
  1WTMARG,WTMARG/DISPFL,VCG(825),DISPFL,DISPFL/DISPFL,CGFLD             OUTP0353
97 FORMAT(1H0,15X,'VRLOAD TOT',F8.1,4X,F6.4,4X,F5.1/1H ,15X,            OUTP0354
  1'LIGHT SHIP',F8.1,4X,F6.4,4X,F5.1/1H ,16X,'WT MARGIN',F8.1,4X,       OUTP0355
  2F6.4,4X,F5.1/1H0,11X,'FULL LOAD DISP',F8.1,4X,F6.4,4X,F5.1)          OUTP0356
C         PRINT FUNCTIONAL ELECTRIC LOADS                               OUTP0357
   PRINT 98                                                             OUTP0358
98 FORMAT(1H-,25X,'DETAILED RESULTS--FUNCTIONAL ELECTRIC LOADS')        OUTP0359
   PRINT 99                                                             OUTP0360
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 99 FORMAT(1H0,10X,'GROUP',4X,'NAME',4X,'CRUISE KW',4X,'BATTLE KW',      OUTP0361
   14X,'24 HR AVG KW'/)                                                   OUTP0362
    DO 100 I=100,900,100                                                  OUTP0363
100 PRINT 101,I,NELC(I/100),ECR(I/100),EBT(I/100),EAV(I/100)              OUTP0364
101 FORMAT(1H ,10X,I3,4X,A8,2X,F7.1,6X,F7.1,8X,F7.1)                      OUTP0365
    PRINT 102,NELC(10),ECR(10),EBT(10),EAV(10),NELC(11),ECR(11),          OUTP0366
   1EBT(11),EAV(11)                                                       OUTP0367
102 FORMAT(1H ,17X,A8,2X,F7.1,6X,F7.1,8X,F7.1/1H0,17X,A8,2X,F7.1,6X,      OUTP0368
   1F7.1,8X,F7.1)                                                         OUTP0369
200 RETURN                                                                OUTP0370
    END                                                                   OUTP0371
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VSUS    VEND    RANGE   LBP     L/B     B/H     CP      CX                      NAME0001
PROP PLTSUS SHP NU BOILSNU REACTNU ENGS NU SHAFTPROPELLRSHFT TYPPROP RPMPROP DIA NAME0002
DEPTH MBLENTH MBBEAM MB PC END  PC MAXSPDELTA CF                                NAME0003
SSEL TYPEMEL TYPNU LOWSDNU MEDSDNU HI SDNU GT GNNU ST GNKW/DIESLKW/GAS TKW/STM G NAME0004
ELC MARG                        HEAT TYPFIN STAB                        OFF ACC  NAME0005
CPO ACC CREW ACCFLAG ACCTRP ACC PASS ACCDAYS DUR                                NAME0006
HULL MATSUPSTMAT        GM/B MIN        DISP TOLMXDIS ITVCG TOL MXVCG ITDCWTMARG NAME0007
FS CORR PRNT TYPPRNTCNST        PASSAGE PROP PLTSSEL TYPEMEL TYP                NAME0008
SHFT TYPPROPELLRFIN STABHEAT TYP        HULL MATSUPSTMATPASSAGE                 NAME0009
                                                                                NAME0010
                                        600 STM 1200 STMPF1200STNUCLEAR GASTURB1 NAME0011
GASTURB2DIESEL  COGAS   STEAM   GASTURB1GASTURB2LOWSPDIEMEDSPDIEHI SPDIEHOLLOW  NAME0012
SOLID   FIXEDPITCONT PITNO      YES     STEAM   ELECTRICSTEEL   ALUMINUMCNTRLINE NAME0013
PORTSTBD                                                                        NAME0014
LBP     BEAM    DRAFT   D 0     D 10    D 20    D AVG   LEN R DKCP      CX      NAME0015
VCG FLD VCG/DAVGL/B     B/H     EXCES KGRANGE   SUS SHP END SHP VSUS    VEND    NAME0016
AVSEASPDNU ACCOMKW INST KW SPSERKW EMERGDISP FLDDISP LSPVR LOADSWT MARG WTGRP 1 NAME0017
WTGRP 2 WTGRP 3 WTGRP 4 WTGRP 5 WTGRP 6 WTGRP 7 VOL TOT VOL HULLVOL SSTRCRUISEKW NAME0018
BATTLEKW24 HR KWNU LOWSDNU MEDSDNU HI SDNU GT GNNU ST GNKW/DIESLKW/GAS TKW/STM G NAME0019
FLD DENSLSP DENSWPAY/FLDWPER/FLDWOPS/FLDVPAY/VOLVPER/VOLVOPS/VOLWTG2/SHPVMB/SHP NAME0020
WT3/KWINWTG1/VOLWTG5/VOLVHAB/MANWHAB/MANMEN/DISPKWIN/FLDSHP/DISPDP*V/SHPWPY*V/DP NAME0021
MIL MISS                                                                        NAME0022
COMM/DETRADIOCOMRADAR   SONAR   ECM     EVALUATEC/D SUPP                        NAME0023
WEAPONS GUNS    MISSILESASW     MINE WARSM ARMS CM NO ELWEAP SUPSPECWEAP        NAME0024
AVIATIONCONTROL STOW/MNTSTORES  LIQUIDS ORDNANCE                                NAME0025
AMPH OPS                                                                        NAME0026
CARGO                                                                           NAME0027
FLAG                                                                            NAME0028
PASSNGER                                                                        NAME0029
SPEC MIS                                                                        NAME0030
                                                                                NAME0031
PERSONEL                                                                        NAME0032
LIVING  OFF BER OFF MESSOFF BATHCPO BER CPO MESSCPO BATHCREW BERCREWMESSCREWBATH NAME0033
SUPPORT ADMIN FNFOOD P&HMED &DENPER SERVREC &WELSEWAGE                          NAME0034
STOWAGE STORES  PER STOWPOTWATER                                                NAME0035
                                                                                NAME0036
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                                                                             NAME0037
                                                                             NAME0038
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                                                                             NAME0040
                                                                             NAME0041
SHIP OPS                                                                     NAME0042
CONTROL SHIP CNTDAM CONTOFFICES                                              NAME0043
MACH SYSMACH BOXUPTAKES SH,BR,PRMANEUVERVENTILAT                             NAME0044
DECK AUXANCH,M&TUNREP                                                        NAME0045
MAINTAINMECHANICELECTRICMISC                                                 NAME0046
STOWAGE FUEL OILR FEED WLUBE OILDIES OILMISC LIQSTOR&SUPBOATS                NAME0047
TANKAGE BALLAST PEAK    VOIDS   XFLOODNGMISC TNK                             NAME0048
PASS&ACC                                                                     NAME0049
HULL MAR                                                                     NAME0050
SUP MARG                                                                     NAME0051
PLATING FRAMING INN BOTMPLATFLAT                      ALL DECK               NAME0052
       SUPERSTRPROP FNDAUX FNDSSTR BKHDTRK&ENCLSTR SPONARMOR   AC T STRCAST&FOR NAME0053
SEACHESTBAL UNITSPEC DRSDRS&HTCH       MASTKGPT       SONAR DMTOWRPLAT       NAME0054
                                                                             NAME0055
                                                                             NAME0056
WELDRIVTFREEFLIQ                                                             NAME0057
                                                                             NAME0058
                                                                             NAME0059
                                                                             NAME0060
                                                                             NAME0061
BOIL&CONPROPUNITMN CONDSSH,BR,PRCOMB AIRUPTAKES PROP CNTMN STM SFW&CONDNCIRC&CWS NAME0062
FOSERSYSLBOILSYS                                                             NAME0063
                                                                             NAME0064
                                                                             NAME0065
                                                                             NAME0066
REPAIRPTOPER FLD                                                             NAME0067
                                                                             NAME0068
                                                                             NAME0069
                                                                             NAME0070
                                                                             NAME0071
EL PWGENPOW SWBDCABLE   LIGHTING                                             NAME0072
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                                                                                       NAME0075
                                                                                       NAME0076
REPAIRPTGEN FLDS                                                                       NAME0077
                                                                                       NAME0078
                                                                                       NAME0079
                                                                                       NAME0080
                                                                                       NAME0081
NAV EQUPIC SYSTSGFC SYSTCM NO ELECM     MFC SYS ASW FCS TORP FCSRADAR   RADIOCOM NAME0082
ELEC NAVSPACTRCKSONAR   ELEC TDS        ELECTEST                                       NAME0083
                                                                                       NAME0084
                                                                                       NAME0085
                                                                                       NAME0086
REPAIRPTCC OPFLD                                                                       NAME0087
                                                                                       NAME0088
                                                                                       NAME0089
                                                                                       NAME0090
                                                                                       NAME0091
HEAT SYSVENT SYSAIR CONDREFER PLHEAF,ETCPLUMBINGFIREMAINFIRE EXTBALSTSYSFRESHWAT NAME0092
SCUPPERSFUELTRANTANKHEATCOMP AIRAUX STM BUOY CNTMISCPIPEDISTILLGSTEERINGRUDDERS  NAME0093
ANCH,M&TSTOR EQPELOPGEARAIR ELEVACARGEARCATS&JBDHYDROFLSSTAB FINUNREP             NAME0094
                                                                                       NAME0095
                                                                                       NAME0096
REPAIRPTAUX FLDS                                                                       NAME0097
                                                                                       NAME0098
                                                                                       NAME0099
                                                                                       NAME0100
                                                                                       NAME0101
HULL FITBOATS   RIG&CANVLAD&GRATNONS B&DPAINTINGDK COVERHULL INSSTORERMSUTIL EQP NAME0102
WKSP EQPGALY EQPLIV FURNOFF FURNM&D FURNRAD SHLD                                       NAME0103
                                                                                       NAME0104
                                                                                       NAME0105
                                                                                       NAME0106
REPAIRPTO&F FLDS                                                                       NAME0107
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                                                                              NAME0111
GUN MNTS                SPWEPH&SMIS LHES                           TORPTH&S   NAME0112
MINE H&SSM ARMS AIR H&ST                                                      NAME0113
CARGOH&S                                                                      NAME0114
                                                                              NAME0115
                                                                              NAME0116
REPAIRPTARM FLDS                                                              NAME0117
                                                                              NAME0118
                                                                              NAME0119
                                                                              NAME0120
                                                                              NAME0121
SHIP OCETRPS&EFFPASS&EFFSHIPAMMOAV AMMO AIRCRAFTPROV&PSTGEN STORMARINESTAERO STR NAME0122
ORDSTRSHORDSTRAVPOTWATERR FEED WLUBOILSHLUBOILAVFUEL OILDIES OILGASOLINEJP-5     NAME0123
MISC LIQCARGO   BALL WAT              D&C MARG                                 NAME0124
PA&STEERAUX MACHDECKMACHSHOPS   IC&ELEX ORDN SYSHOTEL   A/C&VENTPWR CONVELECMARG NAME0125
TOTAL KW                                                                      NAME0126
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.21	.21	.21	.21	.21	.29	.60	1.15	1.77	2.19	2.38	2.40	2.38	2.30	2.20	2.10	CRVS0001
.20	.20	.20	.20	.20	.25	.49	.97	1.55	1.94	2.13	2.20	2.18	2.11	2.03	1.92	CRVS0002
.20	.20	.21	.21	.22	.26	.46	.88	1.38	1.73	1.91	2.00	2.00	1.98	1.91	1.86	CRVS0003
.22	.22	.22	.22	.22	.26	.37	.75	1.20	1.57	1.8	1.88	1.89	1.85	1.79	1.70	CRVS0004
.22	.22	.22	.22	.24	.30	.40	.71	1.12	1.47	1.68	1.75	1.77	1.73	1.68	1.60	CRVS0005
.22	.22	.22	.22	.28	.38	.41	.65	1.06	1.43	1.63	1.71	1.72	1.70	1.66	1.59	CRVS0006
.23	.23	.23	.25	.32	.45	.48	.65	1.03	1.37	1.57	1.66	1.69	1.68	1.62	1.56	CRVS0007
.23	.23	.23	.24	.38	.54	.59	.73	1.07	1.37	1.54	1.64	1.67	1.66	1.60	1.53	CRVS0008
.23	.23	.23	.27	.43	.70	.74	.80	1.10	1.38	1.54	1.63	1.68	1.67	1.60	1.52	CRVS0009
.24	.24	.24	.30	.50	.82	.88	.88	1.15	1.40	1.56	1.63	1.66	1.63	1.60	1.52	CRVS0010
.23	.23	.23	.33	.53	.94	1.05	.98	1.19	1.41	1.55	1.63	1.67	1.65	1.60	1.55	CRVS0011
.24	.24	.24	.40	.63	1.11	1.21	1.13	1.28	1.43	1.57	1.63	1.65	1.65	1.60	1.56	CRVS0012
.25	.25	.26	.35	.41	.47	1.03	2.23	3.73	4.84	5.40	5.53	5.51	5.39	5.07	4.53	CRVS0013
.25	.27	.28	.31	.38	.43	.89	1.90	3.29	4.43	5.05	5.25	5.26	5.12	4.83	4.37	CRVS0014
.26	.26	.27	.30	.37	.42	.82	1.74	3.00	4.16	4.80	5.02	5.05	4.90	4.60	4.22	CRVS0015
.28	.28	.28	.30	.40	.47	.73	1.54	2.71	3.84	4.55	4.80	4.80	4.68	4.40	4.10	CRVS0016
.28	.28	.28	.30	.45	.60	.78	1.45	2.55	3.65	4.33	4.58	4.60	4.48	4.24	3.92	CRVS0017
.28	.28	.28	.32	.51	.77	.88	1.40	2.45	3.48	4.12	4.38	4.39	4.30	4.10	3.85	CRVS0018
.28	.28	.28	.37	.59	1.00	1.03	1.41	2.34	3.33	3.90	4.17	4.20	4.13	3.95	3.80	CRVS0019
.28	.28	.28	.40	.68	1.23	1.20	1.54	2.38	3.28	3.81	4.04	4.10	4.02	3.86	3.62	CRVS0020
.30	.30	.30	.43	.77	1.48	1.49	1.70	2.41	3.19	3.73	3.97	3.99	3.95	3.81	3.60	CRVS0021
.28	.29	.32	.51	.89	1.72	1.83	1.89	2.46	3.23	3.69	3.90	3.95	3.90	3.79	3.64	CRVS0022
.28	.28	.32	.60	.98	1.97	2.10	2.07	2.52	3.24	3.68	3.87	3.92	3.89	3.78	3.61	CRVS0023
.30	.30	.37	.70	1.11	2.22	2.44	2.28	2.64	3.30	3.68	3.87	3.93	3.90	3.77	3.60	CRVS0024
.25	.25	.25	.27	.28	.34	.66	1.20	1.73	2.18	2.40	2.45	2.44	2.39	2.30	2.17	CRVS0025
.25	.25	.25	.32	.38	.42	.69	1.10	1.60	2.06	2.28	2.35	2.32	2.25	2.17	2.11	CRVS0026
.26	.26	.27	.39	.46	.48	.66	1.02	1.46	1.94	2.13	2.17	2.17	2.13	2.08	2.00	CRVS0027
.27	.27	.27	.40	.51	.51	.69	.97	1.38	1.83	2.03	2.10	2.09	2.04	1.96	1.93	CRVS0028
.28	.28	.28	.42	.57	.62	.67	.88	1.32	1.71	1.90	1.96	1.97	1.95	1.90	1.86	CRVS0029
.30	.30	.30	.43	.58	.68	.71	.89	1.29	1.63	1.81	1.90	1.92	1.90	1.86	1.80	CRVS0030
.30	.30	.31	.45	.59	.70	.76	.90	1.23	1.58	1.77	1.83	1.87	1.85	1.80	1.73	CRVS0031
.30	.31	.32	.42	.60	.77	.81	.90	1.20	1.54	1.72	1.79	1.80	1.80	1.74	1.70	CRVS0032
.33	.33	.33	.40	.62	.85	.90	.95	1.19	1.50	1.70	1.75	1.76	1.74	1.70	1.65	CRVS0033
.35	.35	.36	.40	.63	.90	1.00	1.02	1.25	1.53	1.67	1.75	1.77	1.76	1.70	1.63	CRVS0034
.34	.34	.35	.40	.64	1.05	1.17	1.12	1.25	1.53	1.69	1.74	1.76	1.75	1.70	1.62	CRVS0035
.35	.35	.36	.40	.65	1.20	1.37	1.22	1.25	1.53	1.68	1.74	1.76	1.75	1.70	1.61	CRVS0036

.29	.30	.32	.50	.57	.60	1.13	2.19	3.60	4.90	5.56	5.80	5.76	5.57	5.25	5.05	CRVS0037
.30	.30	.31	.51	.62	.60	1.04	1.93	3.29	4.57	5.31	5.50	5.50	5.40	5.20	4.80	CRVS0038
.33	.33	.33	.52	.66	.66	.97	1.75	3.06	4.27	5.00	5.30	5.30	5.25	5.10	4.90	CRVS0039
.32	.32	.33	.52	.68	.71	.96	1.61	2.80	4.04	4.72	5.00	5.00	5.00	4.80	4.70	CRVS0040
.34	.34	.34	.54	.73	.82	1.00	1.60	2.68	3.80	4.42	4.71	4.80	4.77	4.64	4.40	CRVS0041
.34	.34	.37	.55	.78	.98	1.15	1.65	2.57	3.62	4.26	4.40	4.50	4.50	4.40	4.20	CRVS0042
.37	.38	.40	.57	.83	1.17	1.34	1.70	2.55	3.52	4.17	4.45	4.50	4.55	4.50	4.30	CRVS0043
.38	.38	.40	.58	.88	1.35	1.60	1.85	2.55	3.46	4.08	4.34	4.42	4.42	4.35	4.20	CRVS0044
.38	.38	.41	.59	.94	1.60	1.85	2.02	2.54	3.40	4.05	4.41	4.55	4.50	4.30	4.00	CRVS0045
.40	.40	.48	.63	1.02	1.82	2.07	2.21	2.70	3.44	4.03	4.27	4.35	4.25	4.10	3.80	CRVS0046
.40	.40	.48	.70	1.11	2.07	2.40	2.45	2.80	3.48	4.04	4.28	4.35	4.30	4.10	3.80	CRVS0047
.41	.41	.54	.80	1.24	2.30	2.70	2.71	2.98	3.60	4.05	4.26	4.32	4.30	4.10	3.80	CRVS0048
.30	.30	.30	.41	.48	.47	.64	1.20	1.87	2.35	2.68	2.80	2.80	2.76	2.70	2.60	CRVS0049
.33	.33	.33	.42	.48	.47	.65	1.09	1.63	2.13	2.45	2.59	2.60	2.58	2.50	2.40	CRVS0050
.35	.35	.35	.43	.46	.44	.59	.93	1.48	2.01	2.26	2.37	2.39	2.37	2.31	2.24	CRVS0051
.37	.37	.37	.41	.47	.45	.58	.87	1.34	1.82	2.06	2.17	2.20	2.20	2.13	2.06	CRVS0052
.40	.40	.40	.43	.48	.49	.59	.82	1.24	1.65	1.90	2.00	2.06	2.05	2.00	1.91	CRVS0053
.40	.40	.40	.42	.48	.54	.63	.83	1.23	1.60	1.80	1.93	1.97	1.97	1.91	1.78	CRVS0054
.42	.42	.42	.45	.52	.61	.73	.81	1.18	1.53	1.74	1.87	1.93	1.90	1.85	1.73	CRVS0055
.42	.42	.42	.44	.54	.69	.81	.90	1.16	1.53	1.77	1.89	1.90	1.89	1.80	1.70	CRVS0056
.45	.45	.45	.50	.58	.80	.93	1.00	1.18	1.52	1.73	1.83	1.88	1.85	1.78	1.69	CRVS0057
.47	.47	.47	.56	.67	.90	1.05	1.09	1.23	1.53	1.74	1.85	1.88	1.84	1.77	1.67	CRVS0058
.48	.48	.48	.62	.70	1.00	1.20	1.20	1.30	1.52	1.71	1.85	1.87	1.82	1.74	1.69	CRVS0059
.49	.49	.49	.68	.73	1.10	1.34	1.33	1.37	1.52	1.71	1.84	1.87	1.80	1.72	1.70	CRVS0060
.35	.35	.40	.53	.67	.65	1.13	2.30	3.72	5.00	5.95	6.40	6.50	6.40	6.10	5.50	CRVS0061
.38	.38	.42	.54	.65	.63	1.00	1.95	3.40	4.67	5.50	5.80	5.90	5.80	5.50	5.10	CRVS0062
.41	.41	.43	.53	.60	.63	.89	1.78	3.10	4.33	5.10	5.35	5.40	5.30	5.10	4.90	CRVS0063
.43	.43	.45	.53	.64	.70	.91	1.70	2.90	4.07	4.79	5.00	5.10	5.10	4.90	4.70	CRVS0064
.45	.45	.45	.53	.68	.81	.97	1.62	2.73	3.87	4.60	4.95	5.10	5.00	4.90	4.60	CRVS0065
.45	.45	.47	.53	.72	.91	1.15	1.59	2.62	3.75	4.48	4.90	5.00	5.00	4.90	4.50	CRVS0066
.48	.49	.50	.56	.78	1.10	1.35	1.78	2.64	3.70	4.40	4.74	4.80	4.75	4.60	4.25	CRVS0067
.48	.48	.50	.56	.84	1.30	1.60	1.92	2.63	3.65	4.34	4.65	4.70	4.58	4.40	4.10	CRVS0068
.52	.52	.53	.63	.93	1.53	1.85	2.13	2.77	3.63	4.29	4.61	4.70	4.55	4.35	4.00	CRVS0069
.53	.54	.56	.70	1.01	1.78	2.10	2.32	2.85	3.61	4.24	4.55	4.60	4.50	4.25	3.90	CRVS0070
.55	.55	.58	.79	1.16	2.05	2.40	2.57	3.00	3.67	4.23	4.53	4.55	4.40	4.10	3.80	CRVS0071
.58	.58	.66	.90	1.30	2.30	2.73	2.83	3.20	3.70	4.22	4.50	4.45	4.25	4.00	3.70	CRVS0072

.31	.31	.33	.50	.57	.64	1.50	3.40	5.65	CRVS0073
.31	.31	.34	.43	.52	.60	1.20	1.80	5.10	CRVS0074
.30	.30	.32	.38	.48	.60	1.12	2.60	4.60	CRVS0075
.33	.33	.34	.39	.52	.78	1.07	2.23	4.17	CRVS0076
.33	.33	.35	.40	.58	.86	1.13	2.10	3.90	CRVS0077
.34	.34	.34	.42	.67	1.14	1.30	2.05	3.83	CRVS0078
.34	.34	.35	.46	.79	1.45	1.55	2.10	3.67	CRVS0079
.34	.34	.37	.50	.89	1.76	1.84	2.26	3.65	CRVS0080
.34	.34	.38	.57	1.00	2.09	2.23	2.50	3.68	CRVS0081
.33	.33	.40	.65	1.15	2.43	2.69	2.82	3.80	CRVS0082
.34	.34	.41	.74	1.29	2.75	3.18	3.18	3.90	CRVS0083
.35	.36	.47	.85	1.45	3.12	3.76	3.63	4.10	CRVS0084
.35	.35	.40	.60	.72	.85	2.00	4.70	7.70	CRVS0085
.35	.36	.39	.50	.60	.74	1.54	3.65	7.00	CRVS0086
.35	.35	.38	.46	.57	.73	1.37	3.30	6.30	CRVS0087
.38	.38	.40	.47	.61	.83	1.37	2.85	5.70	CRVS0088
.38	.38	.40	.48	.70	1.10	1.49	2.72	4.32	CRVS0089
.38	.38	.40	.51	.83	1.45	1.70	2.65	5.20	CRVS0090
.38	.38	.42	.55	.97	1.80	2.00	2.70	4.00	CRVS0091
.39	.39	.43	.62	1.10	2.18	2.43	2.97	5.10	CRVS0092
.40	.40	.46	.69	1.20	2.62	2.95	3.30	5.00	CRVS0093
.40	.40	.48	.77	1.40	3.07	3.56	3.73	5.15	CRVS0094
.40	.40	.50	.86	1.55	3.50	4.23	4.23	5.30	CRVS0095
.40	.42	.57	.98	1.71	4.00	5.03	4.89	5.60	CRVS0096
.40	.41	.48	.70	.88	1.10	2.60	6.00	9.70	CRVS0097
.42	.42	.46	.60	.72	.90	1.90	4.45	9.00	CRVS0098
.42	.42	.43	.52	.67	.83	1.60	4.15	8.10	CRVS0099
.42	.42	.45	.52	.70	.94	1.57	3.80	7.20	CRVS0100
.43	.43	.46	.55	.71	1.26	1.73	3.40	6.80	CRVS0101
.44	.44	.48	.58	.95	1.70	2.00	3.45	6.50	CRVS0102
.45	.45	.50	.63	1.10	2.11	2.45	3.33	6.35	CRVS0103
.45	.45	.50	.70	1.26	2.63	3.05	3.64	6.15	CRVS0104
.47	.47	.53	.78	1.40	3.10	3.70	4.10	5.30	CRVS0105
.46	.48	.57	.86	1.58	3.70	4.46	4.64	6.40	CRVS0106
.45	.46	.58	.95	1.75	4.20	5.33	5.28	6.80	CRVS0107
.47	.49	.68	1.08	1.93	4.90	6.30	6.00	7.05	CRVS0108

.36	.36	.37	.66	.78	.86	1.60	3.40	6.10	CRVS0109
.35	.35	.38	.62	.76	.82	1.40	2.90	5.10	CRVS0110
.38	.38	.39	.60	.77	.81	1.25	2.55	4.75	CRVS0111
.38	.38	.40	.60	.78	.84	1.23	2.45	4.45	CRVS0112
.40	.40	.42	.60	.82	1.00	1.30	2.34	4.20	CRVS0113
.40	.40	.43	.62	.89	1.25	1.50	2.36	3.97	CRVS0114
.42	.42	.44	.64	.99	1.52	1.80	2.50	3.83	CRVS0115
.44	.44	.47	.68	1.08	1.83	2.20	2.70	3.90	CRVS0116
.43	.43	.49	.72	1.20	2.17	2.63	3.01	3.98	CRVS0117
.45	.46	.55	.79	1.35	2.50	3.05	3.34	4.20	CRVS0118
.46	.46	.58	.94	1.50	2.85	3.54	3.75	4.45	CRVS0119
.48	.49	.67	1.07	1.65	3.24	4.04	4.18	4.80	CRVS0120
.41	.41	.45	.76	.95	1.07	2.07	4.75	9.20	CRVS0121
.42	.42	.45	.72	.86	.98	1.80	3.95	7.00	CRVS0122
.44	.44	.47	.68	.83	.96	1.58	3.50	6.50	CRVS0123
.43	.43	.47	.65	.82	.97	1.52	3.13	6.20	CRVS0124
.44	.45	.48	.64	.89	1.15	1.58	3.00	5.54	CRVS0125
.47	.47	.50	.66	.95	1.48	1.83	2.94	5.20	CRVS0126
.47	.47	.52	.70	1.05	1.83	2.36	3.12	5.03	CRVS0127
.50	.50	.54	.73	1.18	2.20	2.77	3.44	5.32	CRVS0128
.50	.51	.58	.80	1.37	2.67	3.30	3.80	5.40	CRVS0129
.53	.53	.62	.89	1.50	3.10	3.90	4.27	5.70	CRVS0130
.53	.53	.68	1.04	1.73	3.55	4.62	4.90	6.17	CRVS0131
.55	.56	.78	1.22	1.90	4.00	5.30	5.60	6.60	CRVS0132
.47	.47	.53	.87	1.10	1.29	2.73	6.10	12.00	CRVS0133
.48	.48	.52	.81	.97	1.17	2.25	4.90	9.00	CRVS0134
.50	.50	.54	.75	.90	1.08	1.90	4.50	8.20	CRVS0135
.52	.52	.54	.72	.87	1.07	1.80	3.80	7.50	CRVS0136
.52	.52	.56	.70	.93	1.25	1.87	3.60	6.70	CRVS0137
.53	.53	.57	.73	1.01	1.69	2.21	3.45	6.25	CRVS0138
.55	.55	.58	.76	1.13	2.13	2.74	3.65	6.10	CRVS0139
.53	.53	.62	.80	1.28	2.58	3.32	4.04	6.75	CRVS0140
.56	.57	.66	.87	1.46	3.09	3.94	4.55	6.80	CRVS0141
.58	.58	.73	.96	1.63	3.60	4.74	5.17	7.20	CRVS0142
.58	.58	.77	1.10	1.84	4.17	5.74	5.95	7.90	CRVS0143
.60	.62	.88	1.31	2.07	4.70	6.45	7.05	8.40	CRVS0144

.42	.42	.49	.70	.88	.95	1.68	3.43	6.00	CRVS0145
.46	.46	.50	.67	.81	.88	1.42	2.91	5.40	CRVS0146
.46	.46	.51	.66	.77	.85	1.30	2.65	4.95	CRVS0147
.50	.50	.54	.67	.77	.96	1.28	2.44	4.45	CRVS0148
.50	.50	.53	.64	.81	1.08	1.38	2.33	4.10	CRVS0149
.52	.52	.54	.63	.88	1.24	1.60	2.45	4.05	CRVS0150
.53	.55	.57	.65	.97	1.47	1.87	2.53	4.10	CRVS0151
.53	.53	.58	.66	1.08	1.75	2.25	2.90	4.15	CRVS0152
.58	.58	.62	.73	1.24	2.10	2.65	3.17	4.30	CRVS0153
.60	.60	.67	.84	1.31	2.48	3.10	3.53	4.50	CRVS0154
.62	.62	.68	.95	1.48	2.86	3.60	3.96	4.73	CRVS0155
.63	.63	.77	1.10	1.64	3.27	4.13	4.38	5.07	CRVS0156
.48	.50	.56	.84	1.09	1.28	2.20	4.63	8.20	CRVS0157
.52	.52	.60	.82	.99	1.16	1.90	4.10	7.10	CRVS0158
.55	.55	.59	.78	.92	1.10	1.72	3.61	6.50	CRVS0159
.55	.55	.61	.80	.92	1.18	1.68	3.30	5.95	CRVS0160
.57	.57	.62	.73	.96	1.33	1.77	3.10	5.50	CRVS0161
.58	.58	.62	.73	1.01	1.51	2.05	3.13	5.30	CRVS0162
.62	.60	.65	.76	1.11	1.76	2.40	3.30	5.20	CRVS0163
.62	.62	.68	.78	1.25	2.10	2.80	3.60	5.30	CRVS0164
.65	.65	.73	.85	1.40	2.50	3.30	3.98	5.55	CRVS0165
.67	.67	.76	.96	1.58	2.95	3.83	4.44	5.80	CRVS0166
.67	.67	.80	1.09	1.75	3.45	4.43	5.00	6.15	CRVS0167
.72	.71	.85	1.23	1.94	3.90	5.15	5.63	6.54	CRVS0168
.55	.56	.65	1.00	1.32	1.60	2.86	5.90	10.40	CRVS0169
.58	.58	.65	.94	1.16	1.35	2.48	5.15	8.80	CRVS0170
.61	.60	.67	.90	1.07	1.30	2.20	4.50	7.90	CRVS0171
.62	.62	.70	.87	1.05	1.36	2.10	4.05	7.40	CRVS0172
.64	.64	.70	.83	1.10	1.53	2.18	3.80	6.90	CRVS0173
.64	.64	.73	.81	1.15	1.79	2.43	3.80	6.50	CRVS0174
.68	.70	.75	.87	1.25	2.13	2.85	3.90	6.30	CRVS0175
.68	.68	.77	.87	1.37	2.55	3.35	4.27	6.20	CRVS0176
.70	.72	.82	.98	1.57	3.05	3.98	4.80	6.50	CRVS0177
.73	.73	.84	1.09	1.77	3.60	4.65	5.30	6.80	CRVS0178
.74	.75	.90	1.20	2.00	4.10	5.35	5.90	7.20	CRVS0179
.77	.77	.95	1.34	2.20	4.30	5.85	6.40	8.6	CRVS0180

.44	.45	.53	.82	1.08	1.31	CRVS0181
.46	.47	.51	.67	.86	1.04	CRVS0182
.47	.47	.48	.59	.77	.94	CRVS0183
.48	.48	.50	.60	.80	1.03	CRVS0184
.50	.49	.51	.63	.90	1.37	CRVS0185
.50	.50	.53	.65	1.07	1.87	CRVS0186
.50	.50	.55	.70	1.23	2.43	CRVS0187
.50	.50	.57	.76	1.40	3.06	CRVS0188
.52	.52	.60	.83	1.55	3.60	CRVS0189
.52	.53	.65	.93	1.74	4.15	CRVS0190
.52	.53	.68	1.03	1.93	4.90	CRVS0191
.52	.56	.76	1.18	2.10	4.80	CRVS0192
.52	.52	.61	1.05	1.32	1.57	CRVS0193
.53	.54	.63	.94	1.10	1.32	CRVS0194
.55	.56	.62	.86	1.02	1.20	CRVS0195
.57	.57	.63	.82	.93	1.20	CRVS0196
.58	.58	.64	.80	1.00	1.43	CRVS0197
.58	.60	.65	.83	1.08	1.87	CRVS0198
.60	.60	.68	.84	1.22	2.40	CRVS0199
.62	.62	.70	.87	1.37	2.91	CRVS0200
.62	.62	.75	.94	1.55	3.50	CRVS0201
.64	.66	.80	1.03	1.75	4.10	CRVS0202
.67	.67	.85	1.17	1.93	4.75	CRVS0203
.67	.71	.96	1.38	2.23	4.90	CRVS0204
.62	.64	.75	1.15	1.56	1.93	CRVS0205
.65	.67	.75	1.10	1.35	1.59	CRVS0206
.68	.69	.75	1.01	1.22	1.46	CRVS0207
.70	.70	.78	.98	1.16	1.51	CRVS0208
.72	.72	.79	.94	1.19	1.70	CRVS0209
.72	.72	.81	.94	1.28	2.00	CRVS0210
.74	.76	.83	.96	1.40	2.42	CRVS0211
.77	.77	.87	1.00	1.56	3.00	CRVS0212
.78	.78	.91	1.10	1.75	3.50	CRVS0213
.80	.80	.97	1.22	1.94	4.30	CRVS0214
.80	.82	1.00	1.32	2.14	4.90	CRVS0215
.82	.83	1.05	1.47	2.40	5.10	CRVS0216

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144 1 209 2 214 4 215 1 221 12 226 1 230 1 232 1 190 1 242 193 217          FFG70007
164 10 219 1 48                                                             FFG70008
400 0 111.5                                                                 FFG70009
1003 41.4                                                                   FFG70010
1825 22                                                                     FFG70011
2131 15000                                                                  FFG70012
2161 9000 0 13000                                                           FFG70013
2250 1.32 1.17 .77 1.11 .94 .93 .99 1.42 1.18 1.33 1.12 2.23 1.72 3.30      FFG70014
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1 34 20 8750 538 0 0 .61 .83 0 0 6 0 0 0 4 2 2 1                                KARA0001
26 .0005 0 0 0 0 5 4                                                             KARA0002
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61 1 2 0 .10 0 10 20 .10 20 0 0 2 1 0 1                                          KARA0004
64 .08                                                                           KARA0005
701 45.0 25.0                                                                    KARA0006
717 12.0                                                                         KARA0007
2121 163500                                                                      KARA0008
31 4 3                                                                           KARA0009
2152 1000                                                                        KARA0010
1013 10                                                                          KARA0011
2250 1.0 .9 .9 1.0 .8 .8 1.0 .5 .6 .5 .7 1.0 .4 .2 .7 .7 .7 .8 .4 .6 .5         KARA0012
2271 .5 .5 .7 8.0                                                                KARA0013
2274 8.5                                                                         KARA0014
100 1 3 1 9 1 25 1 48 1 49 1 57 31 64 1 66 1 71 1 82 4 100 4 102 2 115           KARA0015
126 3200 119 12000 124 2 136 2 134 2 139 2 144 4 143 2 154 2 156 1 158           KARA0016
146 2 32  1 159 80 168 40 173 80 172 8 174 2 180 1 184 12 200 .5 204             KARA0017
166 1 208 1 209 1 212 1 213 1 214 162 217 1 222 12 226 1 242 1 244 1 31          KARA0018
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APPENDIX F

NOMENCLATURE LIST

APPENDIX F

NOMENCLATURE LIST

AEDPWG	Average endurance power per electric generator, horsepower
AHVOL	Available hull volume, cu. ft.
AM	Cross sectional area amidships, sq. ft.
AREA	Projected lateral area above water, sq. ft.
ATVOM	Available tankage volume, cu. ft.
AVAV	Available arrangement volume in hull, cu. ft.
AVEDPW	Average endurance power, horsepower
AVSP	Average sea speed in North Atlantic Ocean, knots
B	Beam at midship waterline, ft.
BEAMMB	Maximum beam of machinery box, ft.
BHRAT	Beam to draft ratio
BM	Metacentric radius, ft.
B/H	Beam to draft ratio
CALPH	Transverse moment of inertia coefficient
C_B	Block coefficient
CG1	Vertical center of gravity of weight group 1, ft.
CG2	Vertical center of gravity of weight group 2, ft.
CG3	Vertical center of gravity of weight group 3, ft.
CG4	Vertical center of gravity of weight group 4, ft.
CG5	Vertical center of gravity of weight group 5, ft.
CG6	Vertical center of gravity of weight group 6, ft.
CG7	Vertical center of gravity of weight group 7, ft.
CGFLD	Vertical center of gravity of ship at full load, ft.
CGLDS	Vertical center of gravity of ship loads, ft.
CGLSP	Vertical center of gravity of light ship, ft.

COGAS	Combined gas turbine and steam plant
C_p	Prismatic coefficient
CPM	Machinery box prismatic coefficient
C_r	Residual resistance coefficient
CR1( )	C_r arrays for
CR2( )	Taylor's Standard Series
CR3( )	Resistance estimate
C_v	Volumetric coefficient
CVK	Correction to minimum machinery box depth to account for structures, ft.
C_{wp}	Waterplane coefficient
C_x	Midship section coefficient
C_α	Same as CALPH
DO	Depth at forward perpendicular, ft.
D10	Depth at amidships, ft.
D20	Depth at after perpendicular, ft.
DAVG	Average hull depth, ft.
DCMARG	Design, construction weight margin (e.g., 10% as 0.10)
DECKHT	Height of deck for payload items and raised deck, ft.
DELCF	Frictional resistance correction
DEPMB	Minimum machinery box depth
DHAMIN	Minimum deckhouse volume, cu. ft.
DHSV	Smallest deckhouse volume, cu. ft.
DHV	Deckhouse volume, cu. ft.
DISPFL	Full load displacement, tons
DISPLS	Light ship displacement, tons
DISTOL	Tolerance for displacement iteration

DPROP	Diameter of propeller, ft.
DPTRY	Displacement estimate, tons
DSEDPW	Design endurance power, horsepower
DUR	Duration of voyage for stores, days
DURPAS	Duration of stores for passengers, days
DURTRP	Duration of stores for troops, days
EAV( )	Array for storing 24 hour average electric loads, KW
EBT( )	Array for storing battle electric loads, KW
ECR( )	Array for storing cruise electric loads, KW
EDPWPE	Power required per engine at endurance speed, horsepower
EHP	Effective horsepower
EHPAPP	Effective horsepower with appendages
EHPBH	Effective horsepower bare hull
ELMARG	Electric load margin (e.g., 30% as 0.30)
EMETYP	Emergency electric plant type
ENCVOL	Total internal volume of ship, cu. ft.
ENDUR	Ship endurance range, nautical miles
EXCKG	Excess center of gravity height beyond that required by stability criteria, ft.
FO	Freeboard at forward perpendicular, ft.
F7	Flare factor
F10	Freeboard at amidships, ft.
F20	Freeboard at after perpendicular, ft.
FAVG	Average freeboard, ft.
FINST	Fin stabilizers
FLDISP	Full Load displacement, tons

FNDEN( )	Array for storing the calculated density for each function, lbs./cu. ft.
FRAUXB	Fuel rate for auxiliary boilers, lbs. / hr.
FRCGAS	Fuel rate for COGAS propulsion plants, lbs./hr.
FRDIEG	Fuel rate for diesel electric generators, lbs./hr.
FRSTM	All purpose fuel rate for steam plants, lbs./hr.
FSCORR	Stability free surface correction, ft.
GM	Metacentric height, ft.
GMBMIN	Minimum GM/B stability value
GM/B	Ratio of metacentric height to beam
H	Full load draft, ft.
HABCVK	Minimum height of machinery box above CVK, ft.
HCOR	Correction to minimum machinery box depth to account for hull shape, ft.
HTTYP	Type of heating
HULMAT	Type of hull material
HVAW	Hull volume above waterline, cu. ft.
HVBW	Hull volume below waterline, cu. ft.
ICONST	Variable used to control printing status for miscellaneous coefficients
IT( )	Array used to store payload item numbers
JHPOPT	Variable used to set type of speed-power calculations required
KB	Height of the center of buoyancy, ft.
KELEC	Variable used to set type of electric plant calculations required
KG	Height of the center of gravity, ft.

KGEOM	Variable used to set type of geometry calculations required
KGTRY	KG estimate, ft.
KW24AV	24 hour average electric load, KW
KWEMER	Total emergency electric capacity installed, KW
KWINST	Total installed ship service and emergency electric capacity, KW
KWPEMG	KW per emergency generator
KWPRD	KW per diesel generator installed
KWPRGT	KW per gas turbine generator installed
KWPRSG	KW per steam turbine generator installed
KWPSSG	KW per ship service generator
KWSSER	Total ship service electric capacity installed, KW
L	Length between perpendiculars, ft.
LB	Length to beam ratio
LBP	Length between perpendiculars, ft.
LBRAT	Length to beam ratio
LEN	Length between perpendiculars, ft.
LENMB	Machinery box length, ft.
LMB	Same as LENMB
LRD	Raised deck length, ft.
L/B	Length to beam ratio
MXDIS	Maximum number of weight iterations
MXFCKW	Maximum functional electric load, KW
MXITM	Maximum payload item considered
MXVCG	Maximum number of vertical center of gravity iterations
NACC	Total number of accommodations
NACSC	Number of accommodations for ships company

NB	Number of boilers installed
NCOMP( )	Array for storing functional component names
NCPO	Number of CPO's in ships company
NCREW	Number of enlisted crew in ships company
NE	Number of engines installed
NEEND	Number of gas turbine engines required at endurance speed
NELC( )	Array for storing electric group names
NEMG	Number of emergency electrical generators
NFLAG	Number of flag personnel on ship
NGAVG	Number of electric generators for 24 hour electric load
NGFCLD	Number of ship service generators for maximum functional load
NGTG	Number of gas turbine generators installed
NHSD	Number of high speed diesel generators installed
NLSD	Number of low speed diesel generators installed
NMSD	Number of medium speed diesel generators installed
NOFF	Number of officers in ships company
NPASS	Number of passengers on ship
NR	Number of nuclear reactors installed
NS( )	Array for storing specification names
NSHFT	Number of shafts installed
NSHIP	Number of ship being calculated
NSR( )	Array for storing summary of results names
NSSG	Number of ship service generators
NSTG	Number of steam turbine generators installed
NTRP	Number of troops on ship
NTYP( )	Array for storing the type names

NWT( )	Array for storing the weight group names
P( )	Array for storing payload data
PASTYP	Type of passageway
PCEND	Propulsive coefficeient at endurance speed
PCMXSP	Propulsive coefficient at maximum sustained speed
PPTYP	Propulsion plant type
PRPTYP	Propeller type
PRTOUT	Variable used to control the amount of results printed
Q( )	Array for storing the quantity of each payload item used
RATFP	Ratio of endurance power per engine to full power per engine
RDAV	Raised deck arrangements volume, cu. ft.
RHAV	Required hull arrangements volume, cu. ft.
RPM	Propeller revolutions per minute
RSSV	Required superstructure volume, cu. ft.
RTAV	Required tankage arrangements volume, cu. ft.
S( )	Array for storing ship specifications
SFCAED	Average endurance specific fuel consumption, $\frac{\text{lbm}}{\text{SHP}\cdot\text{HR}}$
SFCFP	Full power specific fuel consumption, $\frac{\text{lbm}}{\text{SHP}\cdot\text{HR}}$
SHFTYP	Shaft type
SHP	Shaft horsepower required at maximum sustained speed
SHPE	Shaft horsepower required at endurance speed
SLRAT	Speed to length ratio, knots/ft$^{\frac{1}{2}}$
SSETYP	Ship service electric plant type
SSMAT	Superstructure material type
T	Tankage coefficient
TAAV	Total available arrangements volume, cu. ft.

TANKVL	Tankage volume, cu. ft.
THV	Total hull volume, cu. ft.
TRAV	Total required arrangements volume, cu. ft.
V( )	Array for storing volume of functional groups, cu. ft.
VCG	Vertical center of gravity, ft.
VCG( )	Array for storing vertical centers of gravity
VCGTOL	Tolerance for VCG iteration
VEND	Ship endurance speed, knots
VM( )	Array for storing moment of weight groups, ft.--tons
VOLHUL	Internal volume of hull, cu. ft.
VOLMB	Internal volume of machinery box, cu. ft.
VOLSHP	Total internal volume of ship, cu. ft.
VOLSST	Internal volume of superstructure, cu. ft.
VOLTOT	Total internal volume of ship, cu. ft.
VOMPSS	Superstructure volume required for payload items, cu. ft.
VRLOAD	Total weight of load items, tons
VSUS	Maximum continuous sustained speed, knots
VTKREQ	Tankage volume required, cu. ft.
VWT( )	Array for storing weight of functional groups, tons
$V/\sqrt{L}$	Ship speed to length ratio, knots/ft$^{\frac{1}{2}}$
W( )	Array for storing weight group results, tons
WARM	Weight of armor, tons
WBHS	Weight of basic hull structures, tons
WBRGS	Weight of bearings, tons
WDHS	Weight of deckhouse structure, tons
WFAUXB	Weight of fuel oil for auxiliary boilers, tons
WFELEC	Weight of fuel oil for electric generators, tons

WFFL	Weight of free flooding liquids, tons
WFG4	Weight of functional group 4 (hull structures), tons
WFG5	Weight of functional group 5 (ship systems), tons
WFPROP	Weight of fuel for propulsion use only, tons
WGP4	Weight group 4 minus groups 450 and 451, tons
WGP7	Weight group 7 minus groups 750 and 751, tons
WPAYIN	Total weight of payload items input, tons
WPROP	Weight of propellers, tons
WSHAFT	Weight of shafting, tons
WSS	Weight of secondary structures, tons
WTGP1	Weight of BSCI weight group 1, tons
WTGP2	Weight of BSCI weight group 2, tons
WTGP3	Weight of BSCI weight group 3, tons
WTGP4	Weight of BSCI weight group 4, tons
WTGP5	Weight of BSCI weight group 5, tons
WTGP6	Weight of BSCI weight group 6, tons
WTGP7	Weight of BSCI weight group 7, tons
WTMARG	Weight of margin for design/construction, tons
WTSHIP	Full load displacement of ship, tons